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# CANDIDATE SUBSTANCES FOR BANS, PHASE-OUTS OR REDUCTIONS - MULTIMEDIA REVISION

OCTOBER 1993

Ontario

Ministry of
Environment
and Energy

ISBN 0-7778-0774-2

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LOG 93-053505
PIBS 2709

# CANDIDATE SUBSTANCES FOR BANS, PHASE-OUTS, OR REDUCTIONS - MULTIMEDIA REVISION

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## Acknowledgements

The authors wish to express their appreciation to Andrew Chiu, Peter Dennis, Yousry Hamdy, Ivy Jung, Ronald Macfarlane, Lorna Poff, Don Poulton, Iraj Rahmani, Glenn Rutherford, Wolfgang Scheider, Jim Smith and Akos Szakolcai of the Ontario Ministry of Environment and Energy for their contributions to this report and their guidance in its preparation. The authors also wish to thank Ivy Wile, Jim Ashman and Ron Pearson of the Ontario Ministry of Environment and Energy and Jim Pettit, Bruce Archibald and Craig Hunter of the Ontario Ministry of Agriculture and Food for their review comments.

# Executive Summary

In June 1991 the Ontario Ministry of the Environment's Hazardous Contaminants Branch and Water Resources Branch were directed to establish a list of candidate substances to be considered for banning, phasing out or use/release reductions. The results were: (i) a process for selecting the substances, (ii) primary and secondary lists of substances for consideration, (iii) a review of the data on loadings of the primary list substances to receiving waters from industrial and municipal direct dischargers, (iv) a hazard evaluation of industrial and municipal effluents monitored under MISA[†] and (v) a review of the receiving water impacts, including sediment and biota impacts, attributable to point and non-point source inputs of substances on the Primary List.

The selection process, lists of candidate substances and monitoring/impact reviews were documented in the report entitled "Candidate Substances List for Bans or Phase-Outs", published in April 1992. For this revised report, the scope of the effort was widened to encompass multiple media. This involved the hazard evaluation of substances released primarily to air and to land that were not considered in the first report.

The Primary List of Candidate Substances for Bans, Phase-Outs or Reductions is a list of substances present in or discharged to Ontario's environment which, out of over 1000 substances assessed, *are most inherently hazardous due to their persistence, potential to bioaccumulate and toxicity*. It is recommended that these substances be given first priority in considering candidate substances for banning, phasing out, or use/release reduction, in that order of preference, and with an emphasis on the application of pollution prevention techniques. Determining the appropriate action option would depend in large part on the results of technical feasibility and socioeconomic impact analyses for each substance or group of substances listed.

The revised Primary List is composed of the following 27 substances or substance groups. Arsenic, which appeared on the original list, was transferred to the Secondary List after further review of its bioaccumulation data. The seven substances that have been added to the original list of 21 are marked with an asterisk:

aldrin*
anthracene
benzo[*a*]pyrene
benzo[*ghi*]perylene
benz[*a*]anthracene
cadmium & compounds*
chlordane*
DDT & metabolites
1,4-dichlorobenzene
3,3'-dichlorobenzidine
dieldrin
endosulfan*
endrin*
heptachlor*
hexachlorobenzene
alpha-hexachlorocyclohexane (α-HCH)
gamma-hexachlorocyclohexane (γ-HCH, Lindane)
mercury & compounds
mirex
pentachlorophenol
perylene
phenanthrene
polychlorinated biphenyls (PCBs)
polychlorinated dibenzo-p-dioxins and -furans (PCDD/Fs)
toxaphene
tributyl tin
trifluralin*

[†] Municipal-Industrial Strategy for Abatement, a program under which effluents from industrial and municipal sources directly discharged to surface water are monitored and regulated.

Analyses of the environmental impact of the Primary List substances in the surface water and sediment media are given in this report. Considerable information is available on the loadings and environmental impacts of the Primary List substances to water and sediment, however comparable information is not available for air and land. As a result, corresponding impact analyses from the perspectives of air and land could not be provided.

Although all Primary List substances except 3,3'-dichlorobenzidine and trifluralin have been detected at elevated concentrations in the water, sediment or aquatic biota of the Great Lakes basin, it has been demonstrated that 22 of the substances have caused impairments of water, sediment or biota in Ontario based on exceedences of available criteria. Of the other five substances, 1,4-dichlorobenzene and toxaphene have not been detected at levels which exceed established criteria, 3,3'-dichlorobenzidine and tributyl tin could not be evaluated from the perspective of water/sediment/biota impairment because no appropriate criteria have been established for these substances, and no data were available for trifluralin.

Twenty-four of the Primary List substances have been monitored under Ontario's MISA program or in the Municipal Water Pollution Control Plants Study[†]. It has been demonstrated that of these 24 substances, 17 are being directly discharged to surface waters by Ontario-based industrial point sources or municipal water pollution control plants. Five substances are being discharged at high concentrations considered to be acutely toxic to aquatic biota, including cadmium, mercury, PCBs, polychlorinated dibenzo-p-dioxins and benzo[*a*]pyrene.

A Secondary List of 63 substances divided into three groups is recommended as a "second tier" of candidate substances. These substances are toxic and either persistent or bioaccumulative, or are persistent and/or bioaccumulative but somewhat less toxic than those on the Primary List.

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[†] A 1987 survey of 37 Ontario municipal water pollution control plants.

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# Part I

## Development of a Selection Protocol and Lists of Candidate Substances for Bans, Phase-Outs or Reductions

### 1 Background and Objective

Persistent, bioaccumulative toxic substances present a well-recognized threat to the environment. The Revised U.S./Canada Great Lakes Water Quality Agreement states that "it is the policy of the Parties that ... the discharge of any or all persistent toxic substances be virtually eliminated". In their Sixth Biennial Report on Great Lakes Water Quality (1992), the International Joint Commission (IJC) recommended that persistent, toxic substances be identified and virtually eliminated, and that a date be set after which no point source release of any persistent toxic substances would be permitted into Lake Superior or its tributaries. The September 1992 report of the Ontario Round Table on Environment and Economy, "Restructuring for Sustainability", recommended that "the Government of Ontario end the release of persistent bioaccumulative toxic substances by the year 2000; by the end of 1994, each sector should have developed plans to meet this goal".

Elimination of the release of designated substances, or "zero discharge", was defined by the IJC Virtual Elimination Task Force in their July 1991 interim report as the elimination of all inputs to the Great Lakes Basin ecosystem of persistent toxic substances produced, used, distributed or disposed of in or around the basin, whether from direct release into waterways or the atmosphere, indirect releases such as agricultural and urban runoff, or inadvertent releases such as from spills. To achieve this, all sources of the target substances must be eliminated, rendering those substances unavailable and thus preventing any opportunity for their entry to the environment.

Instruments employed to attain the elimination of a substance may be in the form of a ban on the use and generation of the substance or a phasing out of the use and generation of the substance (*i.e.* incremental reductions leading ultimately to a complete ban). Where a ban or phase-out is not technically or socioeconomically feasible, alternative actions include reduction in the use of the substance or reduction in the release of the substance to the environment.

In June 1991 the Ontario Ministry of the Environment's Hazardous Contaminants Branch and Water Resources Branch were directed to establish a list of candidate substances to be considered for banning, phasing out or use/release reductions. The result was a report published in April 1992 entitled "Candidate Substances List for Bans or Phase-Outs", covering persistent, toxic substances of concern primarily from a surface water perspective. In this revision of that report, the scope of the effort has been widened to encompass multiple media. This involved the evaluation of substances released primarily to air and to land that were not considered in the original report.

The objective of creating a list of candidate substances for bans, phase-outs or use/release reductions was to identify those substances released into or present in Ontario's environment which pose the greatest hazard, based on their potential to

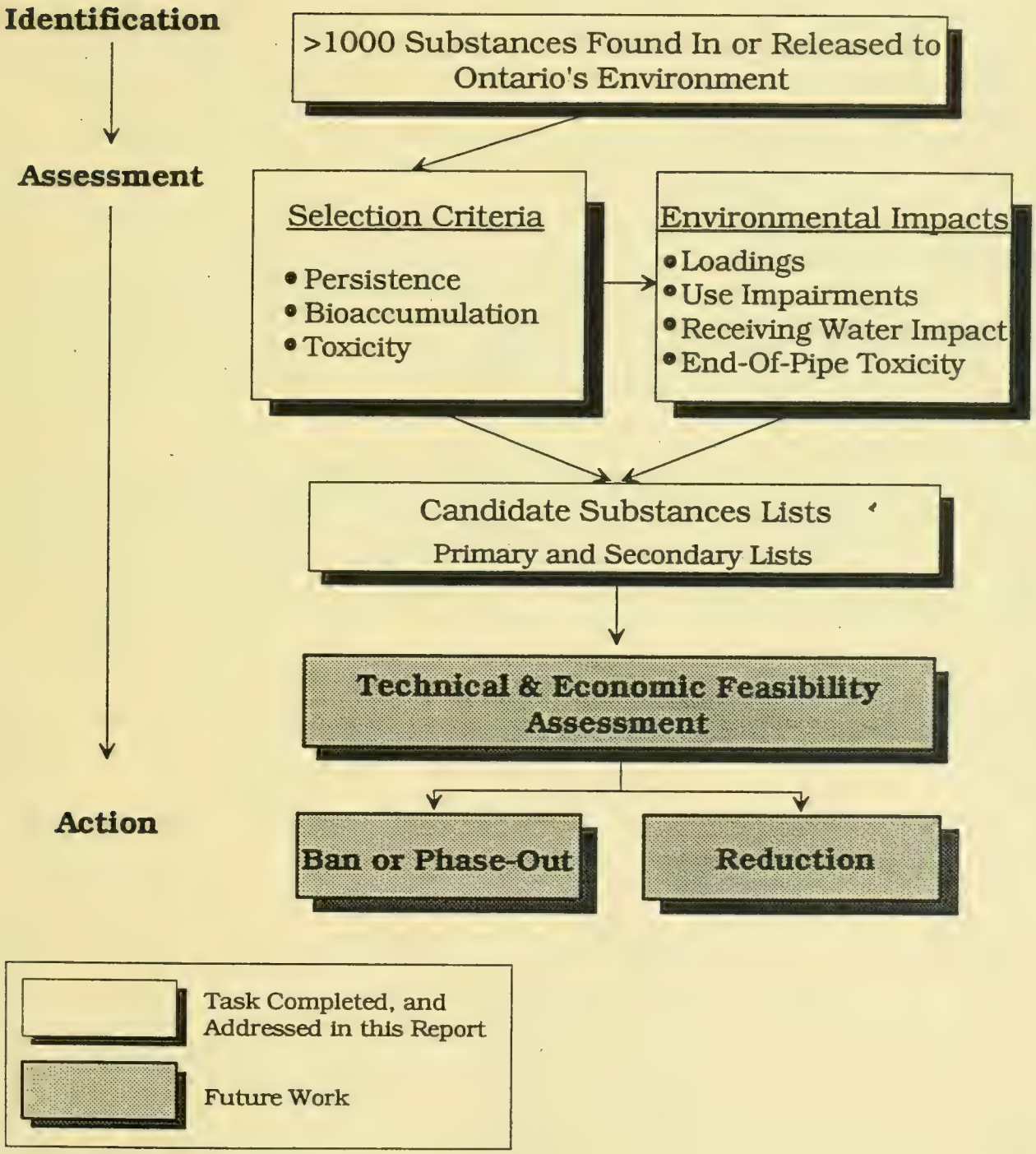
cause adverse impact on the environment. Three general characteristics of substances influence the severity and duration of adverse impacts - persistence, bioaccumulation potential and toxicity, therefore the first step in the process was to identify those toxic contaminants that are persistent in water, sediment, soil or air and are bioaccumulative. Such substances are considered to be candidates for bans, phase-outs or use/release reductions, in that order of preference, with an emphasis on the application of pollution prevention techniques.

The list of candidate substances, therefore, is a list of substances which due to their physicochemical and toxicological properties are most inherently hazardous and should ideally not be permitted to enter the environment. However, of all the substances in the environment, those selected as first priority for consideration for bans, phase-outs or reduction are not necessarily those that present the greatest environmental health *risk* . "Risk" is a function of both exposure level and degree of adverse effect. The limited amount of exposure information available precluded the development of a systematic approach for identifying substances that pose the greatest risk. Risk assessment may be considered at a later stage after detailed exposure-related information has been obtained, *e.g.* environmental concentrations, contaminant loadings from point, diffuse and transboundary discharge sources and further evidence of demonstrable effects on biota at contaminated sites.

The overall process by which substances are selected as candidates for bans, phase-outs or reductions, further assessed and then acted upon through various options is illustrated in Figure 1. Future efforts should involve assessment of exposure potential, assessment of the technical and economic feasibility of bans or phase-outs and the determination of which options for action are appropriate.

# Figure 1

## Selection of Candidate Substances for Bans, Phase-Outs or Reductions



## 2 Previous Bans and Phase-Outs

In Canada, the following industrial chemicals have been banned or are being phased out:

PCBs (polychlorinated biphenyls)
PBBs (polybrominated biphenyls)
PCTs (polychlorinated terphenyls)
Mirex
CFCs (chlorofluorocarbons).

Various courses of action can be taken in the case of pesticides. The registration of the pesticide can be cancelled or its uses suspended (*e.g.* DDT and alachlor), it can be phased out ("discontinued") by allowing the use of existing stocks only (*e.g.* dieldrin), or a manufacturer may decide to withdraw its product from the market before regulatory action is taken to suspend it (*e.g.* chlordane).

A few examples of previous bans and phase-outs are given in Table 1.1 to illustrate the concerns that led to the control of particular substances and factors involved in the decision. The concerns listed are those considered during the regulatory review and do not necessarily represent all of the adverse effects of the compounds, nor does the table include information found after regulatory action was taken. Since the experience in the United States has been similar to that in Canada, only the Canadian situation is presented.

In all cases, the persistence of the chemical resulted in environmental levels that were detrimental or considered potentially harmful. The availability of substitutes and the economic cost of adjustment to a different technology influenced the choice of a rapid ban or gradual phase-out. The potential benefits of banning the substances have always outweighed the costs associated with the bans.

## Table 1.1: Examples of Previous Bans and Phase-Outs

| | | |
|---|---|---|
| **Mirex** | Uses | - In Canada, used as a fire retardant only. |
| | Regulatory history | 1978 All uses prohibited |
| | Environmental concerns | - Persistent in the environment<br>- Widely dispersed from source of emission<br>- Contamination of fish and fish eating birds<br>- Degradation product also persistent and toxic |
| | Health concerns | - Caused tumours in experimental animals<br>- Mirex contained a carcinogenic impurity |
| | Socio-economic factors | - Not imported into Canada since 1969<br>- Alternative chemicals in regular use<br>- No use for which Mirex is indispensable |
| **PCBs** | Uses | - Hydraulic fluids, heat-exchange and dielectric fluids, plasticizers, in pesticides, caulking compounds, adhesive paints, printing ink, carbonless copy paper. Present use is limited to existing transformers. |
| | Regulatory history | 1977 Most non-electrical uses prohibited<br>Manufacture banned in North America<br>1980 Restricted to existing equipment already in use<br>Import of PCB filled equipment prohibited<br>PCBs cannot be used to fill existing equipment<br>(Oils with less than 50ppm PCBs are not considered PCBs)<br>1982 Ontario regulates the transport and storage of PCB waste<br>1985 Sale of PCB equipment prohibited<br>Quantities of PCBs that can be released are restricted |
| | Environmental concerns | - Persistent<br>- Widely dispersed far from source of release<br>- Bioaccumulative<br>- Adverse reproductive effects in fish, fish-eating birds and mink documented at exposure to environmental levels |
| | Health concerns | - Accidental food poisoning resulted in severe effects in Japan<br>- Caused cancer in experimental animals<br>- PCBs could be contaminated with polychlorinated dibenzofurans<br>- Fish caught in Lake Ontario and in the St. Lawrence River often contaminated at levels above Canadian guidelines |
| | Socio-economic factors | - In 1972, Monsanto, the sole producer of PCBs in North America, voluntarily restricted sale to enclosed electrical uses only; voluntarily stopped production in 1977<br>- Alternative heat transfer and hydraulic fluids readily available<br>- Immediate removal of all PCB containing equipment would severely disrupt electricity distribution<br>- Potential adverse effect on the Great Lakes fisheries if unrestricted use continued |
| **Alachlor** | Uses | - To control weeds in a variety of crops |
| | Regulatory history | 1985 Use restricted<br>1986 No longer registered |
| | Environmental concerns | - Use of Alachlor according to label instructions results in ground and surface water contamination |
| | Health concerns | - An animal carcinogen |
| | Socio-economic factors | - Alternatives are readily available<br>- To minimise disruption, use of available stocks of Alachlor was allowed during 1985 |
| **DDT** | Uses | - To control a wide variety of insects and other pests |
| | Regulatory history | 1969 Ontario restricts to 3 specialised uses<br>1972-3 Ontario restricts to control of bats<br>1974 Ontario allows DDT to control mice as well as bats<br>1988 All uses disallowed in Ontario |
| | Environmental concerns | - Persistent in the environment<br>- Widely dispersed from source of emission<br>- Bioaccumulative<br>- Adverse effects on fish-eating birds and predatory fish |
| | Health concerns | - No human health concerns |
| | Socio-economic factors | - Due to pest resistance, other pesticides were regularly being used<br>- More effective and less persistent alternatives available for most uses although sometimes at increased cost |

## 3 Other Agencies' Approaches to Substance Designation

### 3.1 U.S. EPA Pollution Prevention Act, Substances for 50% Reduction

As an initiative under the Pollution Prevention Act, the U.S. EPA identified 17 chemicals for voluntary 50% emission reduction by 1995 (Table 1.2). The following criteria were used to choose the chemicals:

- The top 100 production chemicals on the Toxic Release Inventory
- High percentage release when compared to production volumes
- Technically and economically feasible
- Chemicals subject to the Clean Air Act
- Exposure levels indicate a potential risk to health or the environment
- Significant releases are occurring
- Multiple exposure and cross-media contamination potential are high or hot-spots are known to exist
- Current treatment and disposal methods are not completely satisfactory

### 3.2 U.S. EPA Clean Air Act, Substances for 90% Reduction

Under the Clean Air Act, the U.S. EPA has identified 35 high risk air pollutants for which 90% emission reduction will have to be achieved by January 1st, 1994 (Table 1.3). The procedure used to select those chemicals is as follows:

Tier 1: For the 189 substances on the Clean Air Act Toxic Release Inventory, toxicity data (human toxicity only) was collected (carcinogenicity, reproductive toxicity, acute toxicity and "other" toxicity);

Tier 2: A model was used to predict the maximum dose an individual would receive at a distance of 500m from the source, assuming an emission rate of 10 tonnes per year. Two benchmark doses were then set, *i.e.* $10^{-5}$ lifetime cancer risk, and 10 x reference dose for other effects;

Tier 3: If one or more sources would lead to exceedence of the benchmark doses above, the substance was listed. Also, the IARC Group A (confirmed human carcinogen) substances benzene, benzidine, chloromethyl methyl ether and bis(chloromethyl)ether were added to the list.

### 3.3 U.S. EPA Great Lakes Water Quality Initiative - Bioaccumulative Chemicals of Concern

The 1993 U.S. EPA *Pollutants of Initial Focus in the Great Lakes Water Quality Initiative, List 'A', Bioaccumulative Chemicals of Concern* consists of 28 substances which pose serious risks to human health due to their high toxicity and high bioconcentration potential (Table 1.4). These substances bioconcentrate in fish and shellfish to levels hazardous to human health, even when present in ambient water at very low concentrations. For this list the EPA defined "high bioaccumulation" as a

bioaccumulation factor exceeding 1000, however they did not provide any specific criteria for defining "high toxicity".

### 3.4 IJC Water Quality Board List of Critical Water Pollutants

The International Joint Commission (IJC)'s Water Quality Board has listed 11 critical water pollutants including PCBs, 2,3,7,8-TCDD and benzo[*a*]pyrene and the pesticides DDT, dieldrin, mirex and toxaphene (Table 1.5). The Board's "best professional judgement" selections were based on toxicity, bioconcentration and persistence, however specific criteria are not available. Note that of the pesticides on the IJC's list, all but dieldrin have effectively been banned in Ontario. Dieldrin has minor use, restricted to external structural termite control.

**Table 1.2:** U.S. EPA Pollution Prevention Act
Targeted Chemicals for Voluntary 50% Reduction by 1995

benzene
cadmium & compounds
carbon tetrachloride
chloroform
chromium & compounds
cyanides
dichloromethane
lead & compounds
mercury & compounds
methyl ethyl ketone
methyl isobutyl ketone
nickel & compounds
tetrachloroethylene
toluene
trichloroethane
trichloroethylene
xylenes

---

**Table 1.3:** U.S. EPA Clean Air Act
High Risk Pollutants for 90% Reduction

I. Carcinogens
acrylamide
acrylonitrile
arsenic compounds (inorganic, including arsine)
asbestos
benzene
benzidine
benzotrichloride
beryllium compounds
bis(chloromethyl)ether
1,3-butadiene
cadmium compounds
chlordane
chloromethyl methyl ether
chromium compounds
coke oven emissions
dichloroethyl ether (= bis(2-chloroethyl)ether)
ethylene dibromide (= dibromoethane)
ethylene oxide
heptachlor
hexachlorobenzene
hydrazine
1,2-propylenimine (= 2-methyl aziridine)
2,3,7,8-TCDD
1,1,2,2-tetrachloroethane
vinyl chloride
vinylidine chloride (= 1,1-dichloroethylene)

II. Noncarcinogens
acrolein
acrylic acid
chloroprene
dibenzofurans
mercury compounds
methyl isocyanate
methylene diphenyl diisocyanate
phosgene
2,4-toluene diisocyanate

**Table 1.4:** U.S. EPA Great Lakes Water Quality Initiative
Pollutants of Initial Focus, List 'A': Bioaccumulative Chemicals of Concern (BCCs)

aldrin
4-bromophenyl phenyl ether
chlordane
DDD
DDE
DDT
dieldrin
endrin
heptachlor
heptachlor epoxide
hexachlorobenzene
hexachloro-1,3-butadiene
alpha-hexachlorocyclohexane
beta-hexachlorocyclohexane
gamma-hexachlorocyclohexane (lindane)
delta-hexachlorocyclohexane
technical-grade hexachlorocyclohexane (BHC)
mercury
methoxychlor
mirex
octachlorostyrene
pentachlorobenzene
PCBs
photomirex (chlordecone, kepone)
1,2,3,4-tetrachlorobenzene
1,2,4,5-tetrachlorobenzene
2,3,7,8-TCDD
toxaphene

---

**Table 1.5:** International Joint Commission Water Quality Board
Critical Pollutants List

alkylated lead
benzo[*a*]pyrene
DDT and metabolites (DDE & DDD)
dieldrin
hexachlorobenzene
mercury
mirex
PCBs
2,3,7,8-TCDD
2,3,7,8-TCDF
toxaphene

## 4 Substances Considered

The set of over 1000 substances considered in this exercise were derived from two lists of environmental contaminants. The larger of the two is the "MISA Primary Group" list ("MISA", the Municipal-Industrial Strategy for Abatement, is a monitoring and control program that was initiated by the Ontario Ministry of the Environment in 1986 with the objective of reducing water pollution originating from industrial and municipal dischargers). These are substances identified as being present in Ontario surface water by the International Joint Commission (IJC), the Niagara River Toxics Committee, and through various MOE ambient surface water surveys, as well as substances detected in discharges to Ontario surface water from industrial point sources and municipal sewage treatment plants. The second list is the "CAP Target List", composed of substances of concern released or very likely released directly to air in Ontario.

## 5 Criteria for Listing Substances on the Primary List of Candidate Substances for Bans, Phase-Outs or Reductions

### 5.1 Determination of Criteria

As mentioned in Section 1 above, the first step in selecting candidate substances for bans, phase-outs or reductions was to identify toxic contaminants that are persistent and bioaccumulative. To do so, specific definitions of "persistent", "bioaccumulative" and "toxic" were required.

The rationales for banning particular substances in the past were examined. Unfortunately, specific criteria for banning substances released to the environment do not appear to exist.

Listing criteria had been developed previously for the purpose of placing substances on MISA's Effluent Monitoring Priority Pollutants List (EMPPL). Substances had been evaluated according to a scoring system that considered persistence, bioaccumulation and a number of toxic effects. The scoring system is fully documented in the publication *The Ontario Ministry of the Environment Scoring System* (Ontario Ministry of the Environment, Hazardous Contaminants Branch, 1990); a summary table is provided as Table 1.6.

For a given property, substances receiving a score higher than a defined trigger value were placed on the EMPPL. These trigger values were arrived at using the best professional judgement of a number of Ministry staff from different branches and with various backgrounds. However, the purpose of the EMPPL was to support a monitoring program, and the cutoff values used to develop the EMPPL were more inclusive than those that would be appropriate for a bans/phase-outs initiative. The criteria used to define "persistent" and "bioaccumulative" for the EMPPL were retained for this exercise since they were consistent with precedents established by the IJC, by the Revised Great Lakes Water Quality Agreement and by best professional judgement.

## Table 1.6: Ontario MOE Scoring System Summary Chart

| Parameter Name | Endpoint & Units | Scoring Criteria 0 | 4 | 7 | 10 |
|---|---|---|---|---|---|
| Environmental Persistence | $t_{1/2}$ (days) | ≤10 | >10 to 50 | >50 to 100 | >100 |
| Bioaccumulation | BCF<br>log $k_{ow}$ | ≤20<br>≤2.0 | >20 to 500<br>>2.0 to 4.0 | >500 to 15000<br>>4.0 to 6.0 | >15000<br>>6.0 |

| Parameter Name | Endpoint & Units | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|---|
| Acute Lethality | oral $LD_{50}$ mg/kg | >5000 | >500-5000 | >50-500 | >5-50 | >0.5-5 | ≤0.5 |
| | dermal $LD_{50}$ mg/kg | >5000 | >500-5000 | >50-500 | >5-50 | >0.5-5 | ≤0.5 |
| | inhalation $LD_{50}$ mg/m$^3$ | >15000 | >1500-15000 | >150-1500 | >15-150 | >1.5-15 | ≤1.5 |
| | aquatic $LC_{50}$ mg/L | >1000 | >100-1000 | >10-100 | >1-10 | >0.1-1 | ≤0.1 |
| Chronic/Subchronic Toxicity, Non-Mammals | aquatic<br>$EC_{50}$, mg/L<br>MATC, mg/L<br>NOAEC, mg/L | ≥20<br>≥2<br>≥0.2 | 2-<20<br>0.2-<2<br>0.02-<0.2 | 0.2-<2<br>0.02-<0.2<br>0.002-<0.02 | 0.02-<0.2<br>0.002-<0.02<br>0.0002-<0.002 | <0.02*<br><0.002*<br><0.0002* | <0.02*<br><0.002*<br><0.0002* |
| | terrestrial<br>subchronic<br>NOEL mg/kg/d<br>chronic<br>NOEL mg/kg/d | ≥1000<br>≥500 | 100-<1000<br>50-<500 | 10-<100<br>5-<50 | 1-<10<br>0.5-<5 | <1*<br><0.5*<br>*in one genus | <1*<br><0.5*<br>*in different genera |
| Chronic/Subchronic Toxicity, Plants | Water, mg/L<br>Air, mg/m$^3$<br>Soil, mg/kg | | | | | | |
| | % Mass/Growth Reduction:<br>≤5% (NOAEL)<br>water<br>air<br>soil | <br>>10<br>>100<br>>100 | <br>>1-10<br>>10-100<br>>10-100 | <br>>0.1-1<br>>1-10<br>>1-10 | <br>>0.01-0.1<br>>0.1-1<br>>0.1-1 | <br>0.001-0.01<br>0.01-0.1<br>0.01-0.1 | <br><0.001<br><0.01<br><0.01 |
| | >5-50% ($EC_{50}$)<br>water<br>air<br>soil | <br>>100<br>>1000<br>>1000 | <br>>10-100<br>>100-1000<br>>100-1000 | <br>>1-10<br>>10-100<br>>10-100 | <br>>0.1-1<br>>1-10<br>>1-10 | <br>0.01-0.1<br>0.1-1<br>0.1-1 | <br><0.01<br><0.1<br><0.1 |
| | >50%<br>water<br>air<br>soil | <br>>1000<br>>10000<br>>100000 | <br>>100-1000<br>>1000-10000<br>>1000-10000 | <br>>10-100<br>>100-1000<br>>100-1000 | <br>>1-10<br>>10-100<br>>10-100 | <br>0.1-1<br>1-10<br>1-10 | <br><0.1<br><1<br><1 |
| Chronic/Subchronic Toxicity, Mammals** | oral NOEL mg/kg/day | >1000 | >100-1000 | >10-100 | >1-10 | >0.1-1 | ≤0.1 |
| | inhalation NOEL mg/m$^3$ | >3000 | >300-3000 | >30-300 | >3-30 | >0.3-3 | ≤0.3 |
| Teratogenicity | mg/kg/day | no terata, or terata only at >1000 | terata or developmental anomalies at >50-1000 | terata or developmental anomalies at >10-50 | terata or developmental anomalies at >1-10 | terata at >0.1-1, without overt maternal toxicity | terata at ≤0.1 without overt maternal toxicity |
| Carcinogenicity | human and animal bioassay data | no tumours in adequate studies on at least two species, and does not interact with genetic material | tumours in only one animal species, negative results in others | causes benign tumours in more than one species, and does not interact with genetic material; promotor only; or causes cell transformation *in vitro* only (negative evidence *in vivo*) | tumourigenic in bioassays at doses causing metabolic enzyme saturation, or associated with lesions that predispose to tumours. No interaction with genetic material | indirect-acting carcinogen, no interaction with genetic material | direct-acting carcinogen that interacts with genetic material |

** **Note:** The *Chronic/Subchronic Toxicity, Mammals* criteria are based on studies of ≥90 days duration. If only shorter-term subchronic studies are available, the data are modified as follows, for scoring purposes:

Study duration 28-89 days - multiply criteria by 10
Study duration ≤28 days - multiply criteria by 100

The toxicity criteria were established as follows. After examining the scores for a set of approximately 650 substances assessed for MISA, it was determined that choosing a toxicity score of 10 would result in the selection of the most potent 10-15% of substances that were acutely lethal, toxic upon chronic exposure or teratogenic.

For carcinogens, substances were listed if they had been designated as human or animal carcinogens by the International Agency for Research on Cancer (IARC) or by the U.S. EPA.

The listing criteria resulted in the selection of a reasonably sized list of substances of highest concern from the point of view of persistence, bioaccumulation and toxicity.

## 5.2 Specific Criteria

The specific criteria used to list a substance are as follows. These are derived from the criteria provided in *The Ontario Ministry of the Environment Scoring System*:

### I. Persistence

A substance is considered to be persistent if its half-life in water, sediment, soil or air exceeds 50 days. Sludge may be used as a surrogate for sediment. Metals are considered to be persistent in all media.

### II. Bioaccumulation

A substance is considered bioaccumulative if its fish bioconcentration factor (BCF) exceeds 500. In the absence of a BCF, the logarithm of the substance's octanol:water partitioning coefficient (log $k_{ow}$) is used to estimate bioconcentration potential. In the latter case, a substance is considered bioaccumulative if its log $k_{ow}$ exceeds 4.0 but does not exceed 7.0. Note that log $k_{ow}$ was not used to estimate the BCF for polycyclic aromatic hydrocarbons since for these substances log $k_{ow}$ does not correlate well with BCF.

### III. Toxicity

A substance is considered toxic if it meets any of the following criteria:

#### a) Acute Lethality

| | |
|---|---|
| Aquatic $LC_{50}$ | ≤0.1 mg/L, or |
| Oral $LD_{50}$ | ≤0.5 mg/kg, or |
| Dermal $LD_{50}$ | ≤0.5 mg/kg, or |
| Inhalation $LC_{50}$ | ≤1.5 mg/$m^3$ |

**b) Chronic/Subchronic Toxicity**

Aquatic Biota: $EC_{50}$ ≤0.02 mg/L, or
MATC ≤0.002 mg/L, or
NOAC ≤0.0002 mg/L,
in different genera

Terrestrial Non-Mammals:
Subchronic Exposure: effects at ≤1 mg/kg/day, or
Chronic Exposure: effects at ≤0.5 mg/kg/day,
in different genera

Mammals: Exposure ≥90 days: oral NOAEL ≤0.1 mg/kg/day or inhalation NOAEC ≤0.3 $mg/m^3$; or

Exposure 28-<90 days: oral NOAEL ≤1 mg/kg/day, or inhalation NOAEC ≤3 $mg/m^3$

Plants: Aqueous medium:
NOAEL or ≤5% effect @<0.001 mg/L;
$EC_{50}$ or >5-50% effect @<0.01 mg/L;
>50% effect @<0.1 mg/L;

Air medium:
NOAEL or ≤5% effect @<0.01 $mg/m^3$;
$EC_{50}$ or >5-50% effect @<0.1 $mg/m^3$;
>50% effect @<1 $mg/m^3$;

Soil medium:
NOAEL or ≤5% effect @<0.01 mg/kg;
$EC_{50}$ or >5-50% effect @<0.1 mg/kg;
>50% effect @<1 mg/kg.

**c) Teratogenicity**

Teratogenic effects observed without overt maternal toxicity at maternal exposures ≤0.1 mg/kg/day (or equivalent inhalational or dermal dose) during organogenesis.

**d) Carcinogenicity**

Human or animal carcinogen according to IARC or U.S. EPA classification, *i.e.* classified by IARC as a Group 1, 2A or 2B carcinogen or by the U.S. EPA as a Group A, B1 or B2 carcinogen.

## 6 Sources of Environmental Fate and Toxicity Information

For each substance considered, the information contained in the CESARS[†] database and in the Hazardous Contaminants Branch's assessment files was utilized. These files contain hazard assessments of environmental contaminants prepared by the Hazardous Contaminants Branch in support of Ministry programs, as well as chemical evaluations produced by the Michigan Department of Natural Resources. The assessments are based upon information obtained from an extensive range of sources including on-line factual and bibliographic databases. Where persistence, bioaccumulation or toxicity data were lacking, such information was sought out and retrieved if available from various other sources. In addition, all key information was reviewed and verified prior to the preparation of the final list.

## 7 The Primary List of Candidate Substances for Bans, Phase-Outs or Reductions

Those substances identified in the Ontario environment or identified in emissions to the Ontario environment that meet or exceed the criteria described in Section 5.2 above are considered to be persistent, bioaccumulative and toxic. These substances are to be given first consideration as candidates for bans, phase-outs or reductions, in that order of preference. These substances appear on the Primary List (Table 1.7). Note that this multimedia revision of the list has resulted in the addition of seven substances to the original April 1992 Primary List of 21 substances or substance groups. Arsenic, which appeared on the original list, has been transferred to the Secondary List after further review of its bioaccumulation data. An expanded list showing the Ontario Ministry of the Environment Scoring System scores for each substance is provided in Appendix 'A'.

Note that the Primary List contains six of the seven non-pesticide substances on the IJC Critical Pollutants List. The exception, alkylated lead, is not bioaccumulative according to the criterion selected (tetraethyl lead appears on the Secondary List, Group "A"). **Note also that all of the pesticides on the IJC list have been effectively banned in Ontario except for dieldrin which has minor use as a structural termiticide.**

Factsheets are provided in Section 10 of this report for each substance on the Primary List, containing summarized data on their uses, environmental fate and toxicity.

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[†] Chemical Evaluation Search and Retrieval System, a comprehensive database containing information on environmental contaminants maintained jointly by the Ontario Ministry of the Environment and the Michigan Department of Natural Resources.

**Table 1.7:** Primary List of Candidate Substances for Bans, Phase-Outs or Reductions (Revised)

| CAS Number | Substance Name |
|---|---|
| 309-00-2 | aldrin* |
| 120-12-7 | anthracene |
| 50-32-8 | benzo[*a*]pyrene |
| 191-24-2 | benzo[*ghi*]perylene |
| 56-55-3 | benz[*a*]anthracene |
| 7440-43-9 | cadmium and compounds* |
| 57-74-9 | chlordane* |
| 50-29-3 | DDT (+ DDD & DDE) |
| 106-46-7 | 1,4-dichlorobenzene |
| 91-94-1 | 3,3'-dichlorobenzidine |
| 60-57-1 | dieldrin |
| 115-29-7 | endosulfan (including isomers & sulphate)* |
| 72-20-8 | endrin* |
| 76-44-8 | heptachlor* |
| 118-74-1 | hexachlorobenzene |
| 319-84-6 | α-1,2,3,4,5,6-hexachlorocyclohexane |
| 58-89-9 | γ-1,2,3,4,5,6-hexachlorocyclohexane (lindane) |
| 7439-97-6 | mercury and compounds |
| 2385-85-5 | mirex |
| 87-86-5 | pentachlorophenol |
| 198-55-0 | perylene |
| 85-01-8 | phenanthrene |
| n/a | polychlorinated biphenyls |
| n/a | polychlorinated dibenzo-p-dioxins and -furans |
| 8001-35-2 | toxaphene |
| 688-73-3 | tributyl tin |
| 1582-09-8 | trifluralin* |

* - indicates additional substances which did not appear on the Primary List of 21 substances published in April 1992

## 8 The Secondary List of Candidate Substances for Bans, Phase-Outs or Reductions

The Secondary List (Table 1.8) is a second-tier list of candidate substances for bans, phase-outs or use/release reductions. As with the Primary List, the original April 1992 Secondary List has been updated to encompass substances released to multiple media. The Secondary List has been divided into three groups as follows:

a) **Secondary List, Group "A"**

These are substances that meet or exceed the toxicity criteria used to establish the Primary List, and are either persistent or bioaccumulative but not both;

b) **Secondary List, Group "B"**

These substances are persistent and bioaccumulative, and have a toxicity hazard rating one level below that used as criteria for listing on the Primary List. Specifically, these substances received MOE Scoring System toxicity hazard scores of 8 as opposed to 10 for any of the toxic endpoints considered;

c) **Secondary List, Group "C"**

These substances are either persistent or bioaccumulative, but not both, and have a toxicity hazard rating one level below that used as criteria for listing on the Primary List. Specifically, these substances received MOE Scoring System toxicity hazard scores of 8 as opposed to 10 for any of the toxic endpoints considered.

An expanded list showing the Ontario Ministry of the Environment Scoring System scores for each substance is provided in Appendix 'A'.

## Table 1.8: Secondary List of Candidate Substances for Bans, Phase-Outs or Reductions (Revised)

### Group A

| CAS Number | Substance Name |
|---|---|
| 116-06-3 | aldicarb* |
| 90-04-0 | o-anisidine* |
| 7440-38-2 | arsenic & compounds** |
| 1332-21-4 | asbestos* |
| 1912-24-9 | atrazine* |
| 205-99-2 | benzo[*b*]fluoranthene |
| 205-82-3 | benzo[*j*]fluoranthene |
| 207-08-9 | benzo[*k*]fluoranthene |
| 192-97-2 | benzo[*e*]pyrene |
| 7440-41-7 | beryllium, respirable & compounds |
| 117-81-7 | bis(2-ethylhexyl)phthalate |
| 56-23-5 | carbon tetrachloride* |
| 67-66-3 | chloroform |
| 2921-88-2 | chlorpyrifos* |
| 7440-47-3 | chromium ($Cr^{+6}$) compounds |
| 218-01-9 | chrysene |
| 7440-48-4 | cobalt & compounds* |
| 7440-50-8 | copper, soluble compounds |
| 57-12-5 | cyanides* |
| 226-36-8 | dibenz[*a,h*]acridine |
| 224-42-0 | dibenz[*a,j*]acridine |
| 53-70-3 | dibenz[*a,h*]anthracene* |
| 194-59-2 | 7H-dibenzo[*c,g*]carbazole |
| 189-55-9 | dibenzo[*a,i*]pyrene |
| 107-06-2 | 1,2-dichloroethane* |
| 57-97-6 | 7,12-dimethylbenz[*a*]anthracene |
| 42397-65-9 | 1,8-dinitropyrene |
| 123-91-1 | 1,4-dioxane |
| 122-66-7 | 1,2-diphenylhydrazine |
| 106-93-4 | ethylene dibromide |
| 75-21-8 | ethylene oxide* |
| 206-44-0 | fluoranthene* |
| 77-47-4 | hexachlorocyclopentadiene |
| 193-39-5 | indeno[1,2,3-*cd*]pyrene |
| 7439-92-1 | lead & compounds |
| 75-09-2 | methylene chloride* |
| 7440-02-2 | nickel, respirable forms* |
| 129-00-0 | pyrene |
| 7440-22-4 | silver, as $Ag^{+}$ ion |
| 58-90-2 | 2,3,4,6-tetrachlorophenol |
| 62-56-6 | thiourea |
| 7440-61-1 | uranium & compounds |
| 7440-66-6 | zinc, soluble & respirable compds. |

### Group B

| CAS Number | Substance Name |
|---|---|
| 7429-90-5 | aluminum, soluble compounds |
| 108-90-7 | chlorobenzene |
| 87-68-3 | hexachlorobutadiene |
| 67-72-1 | hexachloroethane |
| 608-93-5 | pentachlorobenzene |
| 7782-49-2 | selenium compounds |
| 95-95-4 | 2,4,5-trichlorophenol |
| 115-86-6 | triphenyl phosphate |

### Group C

| CAS Number | Substance Name |
|---|---|
| 83-32-9 | acenaphthene* |
| 7005-72-3 | 4-chlorophenyl phenyl ether |
| 21725-46-2 | cyanazine* |
| 78-87-5 | 1,2-dichloropropane* |
| 7439-96-5 | manganese compounds* |
| 1945-53-5 | palustric acid |
| 122-34-9 | simazine* |
| 634-90-2 | 1,2,3,5-tetrachlorobenzene |
| 79-34-5 | 1,1,2,2-tetrachloroethane* |
| 2539-17-5 | tetrachloroguaiacol |
| 4901-51-3 | 2,3,4,5-tetrachlorophenol |
| 87-61-6 | 1,2,3-trichlorobenzene |

* - Indicates additional substances which did not appear on the Secondary List of 46 substances published in April 1992.

** - Arsenic & compounds were formerly on the (1992) Primary List.

## 9 Pesticides on the Candidate Substances Lists

Pesticides are toxic by definition, at least to target species. Some are also persistent and/or bioaccumulative. It is recognized that legislation is currently in place at both the federal and provincial levels for regulating pesticides, assessing their hazard and minimizing the risks associated with their use.

Some pesticides have been found in the environment at levels warranting concern. It is therefore appropriate to seek reductions in the use of those substances, through eliminating unnecessary applications, replacing them with less hazardous alternatives where available and applying new approaches to minimize their use such as integrated pest management. This is consistent with the objectives of the Ontario Ministry of Agriculture and Food's "Food Systems 2002" program and with the 1992 Agriculture and Food Sectoral Task Force Report of the Ontario Round Table on Environment and Economy.

## 10 Review of the Substances on the Primary List

A set of factsheets follow containing basic descriptions of the physical-chemical properties of the substances on the Primary List and summarized information regarding the substances' uses, environmental fate and toxicity.

## Anthracene

1. Basic Description

CAS#: 120-12-7
Chemical type: Polycyclic aromatic hydrocarbon (PAH)
Molecular weight: 178.22
Solubility: 0.073 mg/l
Vapour pressure: $3.7 \times 10^{-6}$ mm Hg (25°C)
Log Kow: 4.45

2. Sources and Uses

Present in coal tar, constituent of crude oil heavy fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned. Used in the manufacture of anthraquinone dyes and alizarin dyes.

3. Toxicity and Environmental Fate

Anthracene is a polycyclic aromatic hydrocarbon (PAH) which has been shown to bioaccumulate in freshwater fish tissues. Bioconcentration factors have been reported as being 480-910X. In general, PAHs are thought to be rapidly metabolized by fish but not by freshwater invertebrates which absorb and bioaccumulate them. Anthracene is highly persistent in soil (half-life 50 days to 1.26 years) and sediment (half-life up to 16.5 weeks) but is not persistent in surface water or air.

Anthracene displays very high acute toxicity to aquatic organisms including fish and freshwater invertebrates.

# Aldrin

1. Basic Description

CAS#: 309-00-2
Chemical type: organochlorine
Molecular weight: 364.9
Solubility: 0.02 mg/L (20°C)
Vapour pressure: $3.75 \times 10^{-5}$ mm Hg (20°C)
Log Kow: 5.1-7.4

2. Sources and Uses

Aldrin is an organochlorine pesticide which is currently banned in the United States. In Canada it has limited use as a structural termiticide where its discontinued status under the federal Pest Control Products Act allows use of existing stocks.

3. Toxicity and Environmental Fate

Aldrin is moderately to highly persistent in soil where it is readily converted to dieldrin. The half-life of aldrin in soils has been estimated as being in the range of 20 days to greater than 1 year depending on soil type and moisture conditions. Aldrin is expected to adsorb strongly to soils and hence leaching to most groundwaters is not expected. It is also expected to adsorb strongly in sediments and biodegradation in both soils and sediments will be slow. Aldrin is not persistent in air and degrades rapidly in water. It is expected to bioaccumulate in the food chain with bioconcentration factors in freshwater fish tissues reported in the range of 400 to 2900X and factors as high as 100,000X in freshwater invertebrates.

Aldrin displays very high acute and chronic toxicity to aquatic organisms and has been shown to be highly toxic via chronic ingestion in experimental animals. Based on evidence of tumour induction in experimental animals, the U.S. EPA has classified aldrin as Group B2 - probable human carcinogen.

## Benzo[*a*]pyrene

1. Basic Description

CAS#: 50-32-8
Chemical type: Polycyclic aromatic hydrocarbon (PAH)
Molecular weight: 252.3
Solubility: 0.004 mg/l
Vapour pressure: $7.3 \times 10^{-10}$ mm Hg (25°C)
Log Kow: 6.34

2. Sources and Uses

Present in coal tar, constituent of crude oil heavy fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned. Used as a carcinogenic agent in medical research.

3. Toxicity and Environmental Fate

The PAH benzo[*a*]pyrene (B[*a*]P) has been shown to strongly bioaccumulate in fish tissues (bioconcentration factors have been reported as 479, 490, or 2657X depending on tissue/species type). It is highly persistent in soil (half-life 57 days to 1.45 years) and, based on analogy to other PAHs, persistent in sediments (expected biodegradation half-life greater than 7000 hours). It is not persistent in air or surface water.

As with the PAH anthracene, B[*a*]P demonstrates very high acute aquatic toxicity to freshwater fish and invertebrates such as *Daphnia* sp. Chronic aquatic toxicity is also relatively high. The International Agency for Research on Cancer (IARC) has concluded that B[*a*]P is carcinogenic to experimental animals and that it is a probable human carcinogen. B[*a*]P appears on the IJC Critical Pollutants List and the CEPA Priority Toxic Substances List.

## Benzo[*g,h,i*]perylene

1. Basic Description

CAS#: 191-24-2
Chemical type: Polycyclic aromatic hydrocarbon (PAH)
Molecular weight: 276.3
Solubility: 0.26 µg/l
Vapour pressure: $1.1 \times 10^{-11}$ mm Hg (25°C)
Log Kow: 6.51

2. Sources and Uses

Present in coal tar, constituent of crude oil heavy fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned.

3. Toxicity and Environmental Fate

B[*g,h,i*]P is a PAH which has been reported to bioaccumulate in freshwater fish tissues (6816X in minnows) and in invertebrates. It is highly persistent in soils (half-life 590-650 days) and, by analogy to other PAHs, expected to be very persistent in sediments (expected half-life greater than 7000 hours). The available data indicate it is not persistent in air. The persistence in water is not known.

As with several PAHs, B[*g,h,i*]P may have very high acute aquatic toxicity to freshwater invertebrates.

## Benz[*a*]anthracene

1. Basic Description

CAS#: 56-55-3
Chemical type: Polycyclic aromatic hydrocarbon (PAH)
Molecular weight: 228.3
Solubility: 0.0057 mg/l
Vapour pressure: $2.93 \times 10^{-6}$ Pa (20°C)
Log Kow: 5.61

2. Sources and Uses

Present in coal tar, constituent of crude oil heavy fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned.

3. Toxicity and Environmental Fate

B[*a*]A has been reported to strongly bioaccumulate (bioconcentration factor reported to be 347, 850, or 10,000X) in two species of freshwater fish. It is highly persistent in soil (half-life 102 days to 1.86 years) and in sediments (expected half-life may be greater than 7000 hours). It is not persistent in water or air.

As with a number of PAHs, B[*a*]A has been shown to have very high acute toxicity to aquatic organisms such as Fathead minnows and *Daphnia* sp. IARC has concluded that B[*a*]A is carcinogenic to animals and is a probable human carcinogen.

# Cadmium

1. Basic Description

CAS#: 7440-43-9
Chemical type: Metal
Molecular weight: 112.4
Solubility: insoluble

2. Sources and Uses

Cadmium is commonly used as a coating for other metals, in alloys, and in nickel-cadmium batteries. Cadmium compounds are employed as TV phosphors, pigments in glazes and enamels, dyeing and printing textiles, photography, plastic stabilizers, semiconductors, rectifiers, and scintillation counters.

3. Toxicity and Environmental Fate

As an element, cadmium is highly persistent in all media. It is expected to bioconcentrate in the food chain and bioconcentration factors in freshwater fish have been reported as high as 30,000X.

In both short and long term tests, cadmium has been found to be highly toxic to freshwater fish and invertebrates. It is also moderately toxic to aquatic vegetation. In mammals it may be highly toxic via oral ingestion or inhalation. In humans chronic ingestion is associtaed with kidney damage. The International Agency for Research on Cancer (IARC) has concluded that there is limited evidence of carcinogenicity in humans but sufficient evidence in experimental animals. Epidemiological studies indicate occupational exposure to cadmium (fumes and dust) may be associated with an increased risk of prostate or respiratory tract cancers.

# Chlordane

1. Basic Description

CAS#: 57-74-9
Chemical type: organochlorine
Molecular weight: 409.8
Solubility: 0.056 mg/L (20°C)
Vapour pressure: 1 x $10^{-5}$ mm Hg (25°C)
Log Kow: 5.2-6.0

2. Sources and Uses:

Chlordane is an organochlorine insecticide which historically has been used to control various soil insects. Under the federal Pest Control Products Act all domestic uses have been discontinued (existing stocks may be used according to label instructions). Commercial uses have been restricted to the control of subterranean termites. Uses have been severely restricted in the United States and registrants have voluntarily removed chlordane from the market.

3. Toxicity and Environmental Fate

As with other organochlorine insecticides chlordane is highly persistent in the environment, particularly in groundwater where the biodegradation half-life has been reported as up to 7.6 years and in soil where it may persist for 20 years or more. Chlordane has been found to readily bioaccumulate in the food chain with bioconcentration factors in fish tissues reported in the range of 100 to 19,000X.

Chlordane exhibits very high acute and chronic toxicity to aquatic organisms. In mammals, very high chronic oral and inhalation toxicity has been reported and it is a possible human carcinogen.

# DDT (+ DDD & DDE)

## 1. Basic Description

CAS#: p,p'-DDT 50-29-3, p,p'-DDD 72-54-8, p,p'-DDE 72-55-9
Chemical type: organochlorine
Molecular weight: DDT 354.5, DDD 320.5, DDE 318.0
Solubility: DDT 0.0034 mg/l, DDD 0.160 mg/L, DDE 0.014 mg/L (20°C)
Vapour pressure: DDT 0.188 mm Hg (20°C),
DDD $1.02 \times 10^{-6}$ mm Hg (30°C), DDE $6.5 \times 10^{-6}$ mm Hg (20°C)
Log Kow: DDT 3.9-6.2, DDD 6.20, DDE 4.3-7.0

## 2. Sources and Uses

Historically DDT has seen widespread use in North America and the world as a pesticide. It was banned from use in the United States in 1972 and officially banned in Ontario in 1989. DDD and DDE are metabolites and contaminants of DDT.

## 3. Toxicity and Environmental Fate

DDT is extremely persistent in soils, sediments, and water with half-lives reported in the range of 7 days to greater than 30 years. It has been shown to bioaccumulate in many tissue types including fish tissues at concentration factors up to 363,000X. It demonstrates extremely high acute and chronic aquatic toxicity, very high mammalian chronic toxicity, and there is considerable evidence of teratogenicity, mutagenicity, and carcinogenicity.

DDD strongly bioaccumulates in fish tissues (bioconcentration factors have been reported in the range 933 to 6500X). It is highly persistent in soil, sediments, and water with half-lives reported to be as high as 190 years. DDD is extremely acutely toxic to many aquatic organisms including freshwater fish and invertebrates.

DDE is highly persistent in soil and sediments but not in water. Half-lives have been reported to be up to 15 years in soils and up to 1100 days in sediments. As with DDT and DDD, DDE is highly bioaccumulative with concentration factors in fish tissues as high as 50,000X. DDE displays very high toxicity to a wide variety of aquatic vertebrates and invertebrates.

# 1,4-Dichlorobenzene (para-dichlorobenzene)

## 1. Basic Description

CAS# 106-46-7
Chemical Type: Chlorinated organic
Molecular weight: 147.01
Solubility: 87 mg/l
Vapour pressure: 1.76 mm Hg (25°C)
Log Kow: 3.52

## 2. Sources and Uses

Contaminant of commercial grade ortho-dichlorobenzene, a commonly used deodourizing compound. Insecticidal fumigant, miticide; used domestically against clothes moths.

## 3. Toxicity and Environmental Fate

1,4-dichlorobenzene has been shown to have a bioconcentration factor in rainbow trout as high as 1400X depending on stage and tissue type. It is highly persistent in soils (half-life 1 to 6 months) and sediments (based on monitoring data). It is moderately persistent in air (half-life 8.4 to 84 days) and not persistent in water.

1,4-dichlorobenzene has relatively low acute and chronic mammalian toxicity and moderate aquatic toxicity but is a mutagen and demonstrated animal carcinogen (IARC 2B). It appears on the CEPA Priority Toxic Substances List.

## 3,3′-Dichlorobenzidine

1. Basic Description

CAS#: 91-94-1
Chemical Type: Chlorinated organic
Molecular Weight: 253.13
Solubility: 3.1 mg/l
Vapour pressure: $4.2 \times 10^{-7}$ mm Hg (25°C)
Log Kow: 3.56

2. Sources and Uses

Used to manufacture azo dyes and as an intermediate in synthesizing benzidine yellow pigments.

3. Toxicity and Environmental Fate

3,3′-dichlorobenzidine is highly persistent in soils (half-life 1 to 6 months) and will strongly adsorb to sediments. It is not persistent in water or air. It may bioaccumulate in fish tissues in the range 114 to 610X.

3,3′-dichlorobenzidine is a demonstrated animal carcinogen (IARC 2B) and appears on the CEPA Priority Toxic Substances List.

# Dieldrin

## 1. Basic Description

CAS#: 60-57-1
Chemical type: organochlorine
Molecular weight: 380.9
Solubility: 0.200 mg/l (25°C)
Vapour pressure: $7.8 \times 10^{-7}$ mm Hg (25°C)
Log Kow: 5.1-6.2

## 2. Sources and Uses

Dieldrin is an organochlorine pesticide which is currently banned in the United States. In Canada, it has limited use as a structural termiticide where its discontinued status under the federal Pest Control Products Act allows use of existing stocks.

## 3. Toxicity and Environmental Fate

Dieldrin is highly persistent in soil and water with half-lives reported in the range of 175 days to 3 years. It is expected to bioaccumulate in the food chain with concentration factors in freshwater fish tissue reported as high as 77,000X. Dieldrin displays very high acute aquatic and chronic mammalian toxicity.

# Endosulfan

## 1. Basic Description

CAS#: 115-29-7
Chemical type: organochlorine
Molecular weight: 406.9
Solubility: 0.16 mg/L (22°C)
Vapour pressure: $1 \times 10^{-5}$ mm Hg (25°C)
log Kow: 3.62

## 2. Sources and Uses

Endosulfan is an organochlorine pesticide registered for use as a miticide and insecticide to control various agricultural pests and specific home and garden pests. In Ontario up to 14,000 kg were used in the agricultural sector in 1988.

## 3. Toxicity and Environmental Fate

Endosulfan may be highly persistent in soils depending on soil moisture content and soil pH. In dry soils the half-life of endosulfan has been reported as high as 100 days. The half-life of the $\alpha$ and $\beta$ isomers of endosulfan have been reported as 35 (pH 7) to 187 days (pH 5.5). In water a half-life due to hydrolysis of 178 days has been reported. Sediments may be an important sink for endosulfan which may strongly adsorb to particulate matter (silt and mud). Endosulfan is not expected to be persistent in air. Bioaccumulation is expected to occur and bioconcentration factors in freshwater fish tissues have been reported as high as 1741X.

Endosulfan is acutely toxic to freshwater fish and invertebrates.

# Endrin

1. Basic Description

CAS#: 72-20-8
Chemical type: organochlorine
Molecular weight: 380.9
Solubility: 0.25 mg/L (25°C)
Vapour pressure: 2.7 x $10^{-7}$ mm Hg (25°C)
log Kow: 4.6-5.6

2. Sources and Uses

Endrin is an organochlorine pesticide which is banned or severely restricted in the United States. In Canada it retains a discontinued status under the federal Pest Control Products Act which allows for use of existing stocks (limited agricultural uses).

3. Toxicity and Environmental Fate

Endrin is expected to be extremely persistent in soils where biodegradation half-lives of 4 to 14 years have been reported. It is expected to strongly adsorb to soils however leaching to groundwater may be possible under certain soil conditions. In water, endrin is not expected to biodegrade or hydrolyze and half-lives are estimated at greater than 16 weeks to many years. Endrin will also likely sorb strongly and accumulate in sediments.

Endrin has been shown to be acutely toxic to freshwater fish and invertebrates. It has also been shown to be highly toxic via ingestion in chronic studies with rats and dogs.

## Heptachlor

1. Basic Description

CAS#: 76-44-8
Chemical type: organochlorine
Molecular weight: 373.4
Solubility: 0.18 mg/L
Vapour pressure: 4 x $10^{-4}$mm Hg (25°C)
log Kow: 5.27

2. Sources and Uses

Heptachlor is an organochlorine pesticide which has been used for subterranean termite control in the United States. It has never been registered under the federal Pest Control Products Act for termite control in Canada.

3. Toxicity and Environmental Fate

As with other organochlorine pesticides, heptachlor tends to be highly persistent in the environment. In soils, a half-life has been reported of 0.4 to 0.8 years however in other studies mean disappearance rates from soil have been recorded as 5 to 80% after one year. It is not expected to be persistent in air or water. Bioconcentration of heptachlor is expected to be significant and this is supported by bioconcentration factors in freshwater fish reported in the range of 1100X to greater than 20,000X.

Heptachlor is acutely toxic to freshwater fish and invertebrates. Both IARC and the EPA consider heptachlor to be a probable human carcinogen.

## Hexachlorobenzene

1. Basic Description

CAS#: 118-74-1
Chemical Type: Chlorinated organic
Molecular weight: 284.8
Solubility: 0.0062 mg/l
Vapour pressure: $1.9 \times 10^{-5}$ mm Hg (25°)
Log Kow: 5.31

2. Sources and Uses

Used to synthesize other organic chemicals and as a fungicide.

3. Toxicity and Environmental Fate

Hexachlorobenzene has been shown to bioaccumulate in fish in the range 1160 to 35,000X. It is highly persistent in soils (half-life 2.7 to 5.7 years), sediments, and in air (photo-oxidation half-life 156.4 days to 4.2 years) but not in water.

Hexachlorobenzene demonstrates relatively high chronic toxicity in mammals and is a known animal carcinogen (IARC). It appears on the IJC Critical Pollutants List and the CEPA Priority Toxic Substances List.

# α-Hexachlorocyclohexane

1. Basic Description

CAS#: 319-84-6
Chemical Type: Chlorinated organic
Molecular weight: 285
Solubility: 2 mg/l
Vapour pressure: 0.02 mm Hg (20°C)
Log Kow: 3.81

2. Sources and Uses

Byproduct of organic chemical processes, constituent of technical-grade hexachlorocyclohexane, contaminant in lindane (γ-hexachlorocyclohexane) formulations.

3. Toxicity and Environmental Fate

α-HCH has been shown to bioaccumulate in freshwater fish tissues in the range 500 to 1216X. It is highly persistent in soils (half-life 7 to 135 days), and may persist in surface water (hydrolysis half-life estimated to be 500 days to 2 years). It is not persistent in air. Its persistence in sediment is not known.

IARC has determined that there is sufficient evidence that α-HCH is an animal carcinogen.

# γ-Hexachlorocyclohexane (Lindane)

## 1. Basic Description

CAS#: 58-89-9
Chemical type: Chlorinated organic
Molecular weight: 290.82
Solubility: 7 mg/l
Vapour pressure: $3.26X10^{-5}$ mm Hg (20°C)
Log Kow: 3.72

## 2. Sources and Uses

Byproduct of organic chemical processes, constituent of technical-grade hexachlorocyclohexane; used in medicine as a pediculicide and scabicide; and as a veterinary ectoparasiticide. It is registered under the federal Pest Control Products Act as a seed treatment.

## 3. Toxicity and Environmental Fate

γ-HCH may strongly bioaccumulate in freshwater fish tissues in the range 180 to 1613X and is highly persistent in soils (half-life 5.9 days to 2 years), sediments (half-life 4 to 5 years), and in water (hydrolysis half-life 13.8 to 240 days) but not in air.

γ-HCH has very high acute toxicity to fish and other aquatic organisms and relatively high chronic toxicity to mammals. It is a demonstrated carcinogen in animals (IARC 2B).

## Mercury

1. Basic Description

CAS#: 7439-97-6
Chemical Type: Metal
Molecular weight: 200.59
Solubility: 20 µg/l

2. Sources and Uses*

Naturally occurring in coal and mineral ores. Used in barometers, thermometers, hydrometers, pyrometers; in mercury arc lamps producing ultraviolet rays; in switches, fluorescent lamps; in mercury boilers; manufacture of all mercury salts, mirrors; as a catalyst in the oxidation of organic compounds; extracting gold and silver from ores; making amalgams, electric rectifiers, mercury fulminate; also in dentistry; in determining N by Kjeldahl method, for Millon's reagent; as cathode in electrolysis, electroanalysis, and many other uses. Also in pharmaceuticals, agricultural chemicals, anti-fouling paints.

3. Toxicity and Environmental Fate

Bioconcentration factors for mercury in fish tissues have been reported in the range 4000 to 85,000. As an elemental metal it is considered to be extremely persistent in all media.

Mercury displays very high acute toxicity to fish and other aquatic organisms. It is also capable of severe reproductive and teratogenic effects in mammals. Mercury appears on the IJC Critical Pollutants List and the CEPA Priority Toxic Substances List.

[* - Uses as cited in *The Merck Index Online*]

# Mirex

## 1. Basic Description

CAS#: 2385-85-5
Chemical type: organochlorine
Molecular weight: 545.5
Solubility: 0.20 mg/l (24°C)
Log Kow: 5.83

## 2. Sources and Uses

Mirex has historically been used as a flame retardent, antioxidant, antifouling additive in paints, and as an insecticide, particularly to control fire ants in the U.S. Mirex was never registered for use as a pesticide in Canada.

## 3. Toxicity and Environmental Fate

Mirex is strongly persistent in soils and sediments where it may be expected to be bioavailable for up to 600 years. It has been shown to bioconcentrate in fish tissues in the range of 7300 to 28,000X. Mirex displays high aquatic toxicity to both fish and plant life as well as exhibiting high chronic mammalian toxicity, teratogenicity, and carcinogenicity.

## Pentachlorophenol

1. Basic Description

CAS#: 87-86-5
Chemical type: Chlorinated organic
Molecular weight: 266.32
Solubility: 14 mg/l
Vapour pressure: 1.1 x $10^{-4}$ mm Hg (20°C)
Log Kow: 5.12

2. Sources and Uses

Present in effluent from pulp mills using previously treated wood chips. It is currently registered under the federal Pest Control Products Act as a wood preservative and biocide.

3. Toxicity and Environmental Fate

Data from numerous studies indicates PCP is capable of bioconcentrating in the range of 251 to 5370X. It is moderately persistent in soil and air but may be highly persistent in sediments (half-life 42 days to 4.2 years). It is not persistent in water.

PCP demonstrates very high acute and chronic aquatic toxicity and moderate mammalian toxicity.

# Perylene

1. Basic Description

CAS#: 198-55-0
Chemical type: Polycyclic aromatic hydrocarbon
Molecular weight: 252.3
Solubility: 0.0004 mg/l
Log Kow: 6.06

2. Sources and Uses

Present in coal tar, constituent of high-boiling-point petroleum fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned.

3. Toxicity and Environmental Fate

The bioconcentration factor for perylene in minnows has been reported as 1112X. Perylene is believed to be highly persistent in sediments based on analogy to other structurally similar PAHs (half-life expected to be greater than 7000 hours). No information is available on the persistence in air, water, or soils.

Perylene demonstrates very high acute aquatic toxicity to freshwater invertebrates (*Daphnia* sp.).

## Phenanthrene

1. Basic Description

CAS#: 85-01-8
Chemical type: Polycyclic aromatic hydrocarbon (PAH)
Molecular weight: 178.2
Solubility: 1.29 mg/l
Vapour pressure: 0.016 Pa (25°C)
Log Kow: 4.46

2. Sources and Uses

Present in coal tar, constituent of crude oil heavy fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned. A disodium derivative is used as a dehalogenation reagent.

3. Toxicity and Environmental Fate

The PAH phenanthrene has been reported (in two species) to bioconcentrate in fish tissues in the range 1778-5225X. It may be highly persistent in soils (half-life 16 to 200 days) and in water (photolysis half-life up to 69 days) but not in air. Persistence in sediments is not known.

As with a number of PAHs, phenanthrene demonstrates very high acute aquatic toxicity to freshwater invertebrates (*Daphnia* sp.).

## Polychlorinated Biphenyls

1. Basic Description

CAS#: n/a
Chemical type:
Molecular weight: Aroclor 1242 (avg 266.5); Aroclor 1260 (avg 375.7)
Solubility: Aroclor 1242 (0.24 mg/l); Aroclor 1260 (0.0027 mg/l)
Vapour pressure: Aroclor 1242 (0.004 mm Hg (25°C)); Aroclor 1260 (0.0004 mm Hg (25°C))
Log Kow: Aroclor 1242 (4.11); Aroclor 1260 (6.03)

2. Sources and Uses*

Once widely used industrial chemicals whose high stability contributed to both their commercial usefulness and their long-term deleterious environmental and health effects. Used in electrical capacitors, electrical transformers, vacuum pumps, gas-transmission turbines. Formerly used in U.S. as hydraulic fluids, plasticizers, adhesives, fire retardants, wax extenders, dedusting agents, pesticide extenders, inks, lubricants, cutting oils, in heat transfer systems, carbonless reproducing paper.

3. Toxicity and Environmental Fate

PCBs have been reported to bioconcentrate in fish tissues in the range 1076 to over 200,000X. They are extremely persistent in sediments and in water.

PCBs demonstrate very high acute and chronic toxicity to aquatic organisms, are well established as animal carcinogens, and are probable human carcinogens (IARC). PCBs appear on the IJC Critical Pollutants List.

[* - Sources and uses as cited in *The Merck Index Online*]

## Polychlorinated dibenzo-p-dioxins and furans

1. Basic Description

CAS#: n/a
Chemical type:
Molecular weight: 322 (2,3,7,8 TCDD); 306 (2,3,7,8 TCDF)
Solubility: $2 \times 10^{-4}$ mg/l (2,3,7,8 TCDD)
Vapour pressure: $3.46 \times 10^{-9}$ (30°C)(2,3,7,8 TCDD); $2 \times 10^{-5}$ (25°C)(2,3,7,8 TCDF)
Log Kow: 6.15-7.28 (2,3,7,8 TCDD); 5.82 (2,3,7,8 TCDF)

2. Sources and Uses

Contaminant of 2,4,5-trichlorophenol and 2,4,5-trichlorophenoxyacetic acid (the herbicide "2,4,5-T"); formed during the manufacture of trichlorophenols; formed in chlorine bleaching of pulp (in kraft process paper mills); produced during regeneration of catalysts in petroleum refining operations; may be formed when organic material is burned if chlorine is available.

3. Toxicity and Environmental Fate

PCDDs and PCDFs have been shown to bioaccumulate in fish tissues in the range of 240 to 26,000X. They are extremely persistent in soil (half-life may be greater than 10 years), water (half-life 1.15 to 1.62 years) and in sediments (half-life greater than 1 year) but not in air.

PCDDs and PCDFs have been shown to have very high acute and chronic oral toxicity in many species, very high chronic aquatic toxicity, and very strong teratogenic and carcinogenic potential. PCDDs and PCDFs appear on the IJC Critical Pollutants List and the CEPA Priority Toxic Substances List.

# Toxaphene

## 1. Basic Description

CAS#: 8001-35-2
Chemical type: organochlorine
Molecular weight: 414
Vapour pressure: 0.2-0.4 mm Hg (25°C)
Log Kow: 2.9-3.3

## 2. Sources and Uses

Toxaphene was historically used as a vegetable crop insecticide, herbicide, and to control animal ectoparasites. Most uses of toxaphene in the U.S. were banned in 1982. It is not registered for use in Canada.

## 3. Toxicity and Environmental Fate

Toxaphene is highly persistent in soils and in water where the half-life may be as high as 20 years. It has also been shown to strongly bioaccumulate with concentration factors in fish tissue reported as high as 100,000X. It displays extremely high acute and chronic aquatic toxicity and there is considerable evidence of teratogenicity, mutagenicity, and carcinogenicity.

# Tributyl tin

1. Basic Description

CAS#: 688-73-3
Chemical type: Metal-organic
Molecular weight: 291.09
Log Kow: 3.7

2. Sources and Uses

Used as a catalyst for polymerization reactions, in hydrostannation reactions, as a reducing agent, and as a dehalogenating agent. It is registered under the federal Pest Control Products Act as an antifouling additive in marine paints.

3. Toxicity and Environmental Fate

Tributyl tin has been shown to bioconcentrate in fish tissues (in two species) in the range of 257-5020X depending on tissue type. It is highly persistent in soils (half-life 15 to 20 weeks), water (half-life up to 2 years) and in sediments (half-life greater than 200 days). The persistence in air is not known.

Tributyl tin displays very high acute and chronic toxicity to aquatic organisms and is very toxic to aquatic vegetation. Organotin compounds appear on the CEPA Priority Toxic Substances List.

## Trifluralin

1. Basic Description

CAS#: 1582-09-8
Chemical type: organic (dinitroaniline)
Molecular weight: 335.3
Solubility: 0.3 mg/L (25°C)
Vapour pressure: 1.1 x $10^{-4}$mm Hg (25°C)
log Kow: 4.7-5.4

2. Sources and Uses

Trifluralin is a nitroaniline herbicide registered under the federal Pest Control Products Act for use primarily in the pre-emergence control of weeds in field crops and to a lesser extent for weed control in ornamentals. It is used extensively in North America. According to the 1988 Ontario Ministry of Agriculture and Food survey of pesticide use report, up to 138,000 kg were used in that year.

3. Toxicity and Environmental Fate

Information on the environmental fate of trifluralin is limited although given its low water solubility and tendency to partition primarily to soil it should not present a problem to groundwater or surface waters, but rather should strongly adsorb to soils. It is moderately to highly persistent in soil with half-lives in sandy loam soils reported in the range of 42 to greater than 190 days. Under anaerobic conditions the half-life may be considerably shorter. No information on persistence in groundwater is available but studies in the United States indicate that 172 of 2,047 surface water samples and 1 of 507 groundwater samples contained detectable levels of trifluralin. Trifluralin is expected to bioaccumulate based on bioconcentration factors in freshwater fish reported in the range of 240 to 3261X and freshwater invertebrates in the range 20-1250X.

Trifluralin exhibits relatively low acute mammalian toxicity but has been shown to be moderately toxic via chronic ingestion in experimental animals. It is highly toxic to freshwater fish and some invertebrates in acute tests.

# Part II

## Loadings and Environmental Impacts of Substances on the Primary List

### 1 Purpose of This Part of the Report

As discussed in Part I, 27 highly hazardous substances were selected for the primary list of substances being considered for bans, phase-outs or reductions.

The purpose of this part of the report is to:

1) identify whether these substances were found in MISA industrial or municipal sector effluents and provide a summary of point source loadings into Ontario surface waters;

2) conduct a chemical-specific hazard evaluation of MISA effluent discharges; and

3) summarize receiving water impacts or beneficial use impairments that have been identified in Ontario for the Primary List substances.

A corresponding analysis from the perspective of the media of air and land are not provided. This is because (a) the physicochemical nature of the Primary List substances renders all of them relevant in the water and sediment media and (b) whereas considerable information is available on the loadings and environmental impact of the Primary List substances via the water and sediment media, comparable information is not available for releases to air and land.

### 2 Primary List Substances Found in MISA Effluent Discharges and Loadings

#### 2.1 Contaminants Found in Effluents

The MISA industrial monitoring database and the 37 Municipal Water Pollution Control Plants (WPCPs) study database were screened for the presence of the candidate substances (Table 2.1).

For the purpose of this exercise, only quality-controlled and quality-assured effluent monitoring data were assessed. Industrial monitoring data were not available for 3,3'-dichlorobenzidine or any of the pesticides being considered here, i.e. aldrin, chlordane, DDT, dieldrin, endosulfan, endrin, heptachlor, gamma-hexachlorocyclohexane (lindane or gamma-BHC), alpha-hexachlorocyclohexane (alpha-BHC), mirex, toxaphene, tributyltin, and trifluralin. Also, municipal monitoring data were not available for benzo[*g,h,i*]perylene, 3,3'-dichlorobenzidine, perylene, tributyltin, and trifluralin.

## TABLE 2.1 PRIMARY LIST SUBSTANCES FOUND IN EFFLUENTS OF 8 MISA SECTORS

| PARAMETER | ORGANIC CHEMICAL | IRON & STEEL | INORGANIC CHEMICAL | PETROLEUM | PULP & PAPER | MINING | METAL CASTING | MUNICIPAL WPCPs |
|---|---|---|---|---|---|---|---|---|
| aldrin | | | | | | | | |
| cadmium | | present | present | present | present | present | present | present |
| chlordane (total) | | | | | | | | present |
| DDT & metabolites | | | | | | | | |
| 1,4-dichlorobenzene (paradichlorobenzene) | present | | present | | | | | |
| 3,3'-dichlorobenzidine | | | | | | | | |
| dieldrin | | | | | | | | |
| endosulfan (total) | | | | | | | | present |
| endrin | | | | | | | | |
| heptachlor (total) | | | | | | | | |
| hexachlorobenzene | present | present | present | | | present | | |
| alpha-hexachlorocyclohexane | | | | | | | | present |
| gamma-hexachlorocyclohexane (Lindane) | | | | | | | | present |
| mercury | present | present | present | present | present | present | present | present |
| mirex | | | | | | | | |
| PAH/ anthracene | | present | | | | | | |
| PAH/ benzo(g,h,i)perylene | | present | | | present | | | |
| PAH/ benzo[a]pyrene | | present | | | | | | |
| PAH/ benz[a]anthracene | | present | | | | | | |
| PAH/ perylene | | present | | | | | | |
| PAH/ phenanthrene | | present | present | | present | | present | |
| PCB (TOTAL) | present | | present | | | | present | present |
| PCDD-F/ 2,3,7,8-tetrachlorodibenzo-p-dioxin | present | | | | present | | | |
| PCDD-F/ TOTAL heptachlorodibenzofuran (H7CDF) | present | | present | | present | | | |
| PCDD-F/ TOTAL heptachlorodibenzo-p-dioxin (H7CDD) | present | | present | present | present | | | |
| PCDD-F/ TOTAL hexachlorodibenzofuran (H6CDF) | present | | present | | present | | | |
| PCDD-F/ TOTAL hexachlorodibenzo-p-dioxin (H6CDD) | present | | present | | present | | | |
| PCDD-F/ TOTAL octachlordibenzo-p-dioxin (O8CDD) | present | present | present | present | present | | | |
| PCDD-F/ TOTAL octachlorodibenzofuran (O8CDF) | present | present | present | | present | | | |
| PCDD-F/ TOTAL pentachlorodibenzofuran (P5CDF) | present | | present | present | present | | | |
| PCDD-F/ TOTAL pentachlorodibenzo-p-dioxin (P5CDD) | present | | present | | present | | | |
| PCDD-F/ TOTAL tetrachlorodibenzofuran (TCDF) | present | | present | present | present | | | |
| PCDD-F/ TOTAL tetrachlorodibenzo-p-dioxin (TCDD) | present | | present | | present | | | |

/cont'd...

| PARAMETER | ORGANIC CHEMICAL | IRON & STEEL | INORGANIC CHEMICAL | PETROLEUM | PULP & PAPER | MINING | METAL CASTING | MUNICIPAL WPCPs |
|---|---|---|---|---|---|---|---|---|
| pentachlorophenol | | | | | present | | | |
| toxaphene | | | | | | | | |
| tributyl tin | | | | | | | | |
| trifluralin | | | | | | | | |

NOTES: WPCPs = Water Pollution Control Plants

All information obtained from staff of MISA Industrial and Municipal Sections

Seventeen highly hazardous substances on the primary list were found in MISA industrial or municipal sector effluents. Thirteen of these substances were found in industrial discharges and seven were found in municipal discharges.

The substances found included nine organochlorine compounds or chemical groups (chlordane, 1,4-dichlorobenzene, endosulfan, hexachlorobenzene, alpha-BHC, lindane, pentachlorophenol, polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins or dibenzofurans), six polycyclic aromatic hydrocarbons (anthracene, benz[*a*]anthracene, benzo[*g*,*h*,*i*]perylene, benzo[*a*]pyrene, perylene, and phenanthrene), and two metals (cadmium and mercury).

The ten persistent, bioaccumulative and highly toxic chemicals not found in industrial or municipal discharges were aldrin, DDT and metabolites, 3,3'-dichlorobenzidine (no data available), dieldrin, endrin, heptachlor (including its metabolite known as heptachlor epoxide), mirex, toxaphene, tributyltin (no data available) and trifluralin (no data available).

## 2.2 Point Source Loadings of Primary List Substances

### 2.2.1 Industrial Inputs

The annual loadings of the 13 Primary List substances discharged by MISA industrial sectors are summarized in Table 2.2. These loadings should be regarded as preliminary upper bound estimates at this time. Also, loadings for the electric power sector are not available at this time.

The parameters exhibiting the highest total annual loadings were cadmium at 3531 kg/year, and phenanthrene at 665 kg/year primarily because of inputs from the pulp and paper sector. In general, total annual loadings of 1,4-dichlorobenzene, hexachlorobenzene, mercury, PCB, PCP, and other PAH compounds were 200 kg/year or less. Total inputs of dioxins and furans from the inorganic chemicals, pulp and paper, petroleum and the organic chemicals manufacturing sectors were estimated to be less than 0.2 kg/yr.

### 2.2.2 Municipal Water Pollution Control Plant Inputs

The measured annual loadings of the seven Primary List substances discharged by municipal water pollution control plants (WPCPs) in 1987 were as follows:

| | | |
|---|---|---|
| cadmium | - | 1,300 kg/year |
| mercury | - | 1,587 kg/year |
| lindane | - | 22 kg/year |
| PCBs | - | 9 kg/year |
| endosulfan (total) | - | 3 kg/year |
| chlordane (total) | - | 2 kg/year |
| alpha-BHC | - | 1 kg/year. |

## TABLE 2.2 ANNUAL LOADINGS OF PRIMARY LIST CHEMICALS FOUND IN MISA INDUSTRIAL SECTOR EFFLUENTS (kg/year)*

| PARAMETER | ORGANIC CHEMICAL *** | IRON & STEEL | INORGANIC CHEMICAL ** | PETROLEUM | PULP & PAPER | MINING | METAL CASTING | TOTAL |
|---|---|---|---|---|---|---|---|---|
| CADMIUM | | 1460 | 280 | 72 | 139 | 723 | 857 | 3531 |
| 1,4-DICHLOROBENZENE | 177 | - | 2 | - | - | - | - | 179 |
| HEXACHLOROBENZENE | 3 | 2 | 0.2 | - | - | 2 | - | 7 |
| MERCURY | 105 | 7 | 34 | 0.8 | 15 | 33 | 6 | 200 |
| PAH/ ANTHRACENE | - | 4 | - | - | - | - | - | 4 |
| PAH/ BENZO[G,H,I]PERYLENE | - | 44 | - | - | - | - | - | 44 |
| PAH/ BENZO[A]PYRENE | - | 79 | - | - | - | - | - | 79 |
| PAH/ BENZ[A]ANTHRACENE | - | 89 | - | - | - | - | - | 89 |
| PAH/ PERYLENE | - | 12 | - | - | - | - | - | 12 |
| PAH/ PHENANTHRENE | - | 21 | 46 | - | 562 | - | 35 | 665 |
| PCB (TOTAL) | 0.04 | - | 0.09 | - | - | - | 3.650 | 4 |
| PCDD-F/ 2,3,7,8-TCDD | 0.0009 | - | - | - | 0.002 | - | - | 0.003 |
| PCDD-F/ TOTAL H6CDD | 0.0010 | - | 0.003 | - | 0.003 | - | - | 0.007 |
| PCDD-F/ TOTAL H6CDF | 0.008 | - | 0.005 | - | 0.0030 | - | - | 0.02 |
| PCDD-F/ TOTAL H7CDD | 0.005 | - | 0.003 | 0.003 | 0.009 | - | - | 0.02 |
| PCDD-F/ TOTAL H7CDF | 0.007 | - | 0.00005 | - | 0.008 | - | - | 0.02 |
| PCDD-F/ TOTAL O8CDD | 0.01 | 0.002 | 0.02 | 0.008 | 0.028 | - | - | 0.07 |
| PCDD-F/ TOTAL O8CDF | 0.01 | 0.0004 | 0.0002 | - | 0.006 | - | - | 0.02 |
| PCDD-F/ TOTAL P5CDD | 0.003 | - | 0.003 | - | 0.002 | - | - | 0.01 |
| PCDD-F/ TOTAL P5CDF | 0.005 | - | 0.01 | 0.003 | 0.005 | - | - | 0.02 |
| PCDD-F/ TOTAL TCDD | 0.0009 | - | 0.00002 | - | 0.01 | - | - | 0.01 |
| PCDD-F/ TOTAL TCDF | 0.002 | - | 0.02 | 0.003 | 0.03 | - | - | 0.06 |
| PENTACHLOROPHENOL | - | - | - | - | 32 | - | - | 32 |

NOTES: * - THESE YEARLY LOADINGS REPRESENT THE UPPER BOUNDARY

** - SOURCES OF CHLORINATED DIBENZO-P-DIOXINS AND FURANS IN THE INORGANIC CHEMICAL SECTOR ARE UNKNOWN

*** - LOADINGS OF CHLORINATED DIBENZO-P-DIOXINS AND FURANS FOR ORGANIC CHEMICAL MANUFACTURING SECTOR INCLUDE ONLY THOSE FOR DOW CHEMICAL. DATA FROM OTHER PLANTS ARE INSUFFICIENT TO CALCULATE LOADINGS.

The total loadings determined for these 37 WPCPs accounted for approximately 74 percent of the total Ontario flow of municipal wastewaters.

## 2.3 Summary of Point Source Loadings

Based on the available monitoring information, loadings of cadmium from point source discharges into Ontario surface waters are approximately 5000 kg/year and inputs of mercury are greater than 1000 kg/year. For the sum of six PAH compounds, loadings are approximately 1000 kg/year and loadings of 1,4-dichlorobenzene are about 200 kg/year. Also, loadings of chlordane and endosulfan compounds are less than 5 kg/year.

The measured annual loadings of pentachlorophenol, lindane, PCBs, hexachlorobenzene, and alpha-BHC were about 30, 20, 10, 10, and 1 kg/year, respectively. Inputs of polychlorinated dibenzo-p-dioxins and furans are less than 1 kg/year.

It was beyond the scope of this exercise to assess the ecological significance of the total loadings estimates and to predict the potential benefits of remedial control programs. Nonetheless, the loadings provide valuable information for further exposure assessments (*e.g.*, mass-balance modelling) and environmental risk assessments of these highly hazardous substances.

If released into the environment, these persistent, bioaccumulative, toxic substances can bioconcentrate or accumulate in aquatic ecosystems to levels which are harmful to aquatic life and their consumers. Furthermore, anthropogenic inputs of these substances should be curtailed as the difference between tolerable natural background levels and harmful effects in the environment is exceptionally small.

# 3 Hazard Assessment of MISA Effluents

The MISA industrial and municipal monitoring databases were used to conduct a preliminary chemical hazard assessment of industrial waste streams based on concentrations and frequency of exceedences of ambient water quality criteria such as Provincial Water Quality Objectives or Guidelines (PWQO or PWQG) and Great Lakes Water Quality Agreement Specific Objectives (GLWQA specific objectives). Also, effluent concentrations were compared to aquatic toxicity data for laboratory populations exposed during short-term (acute) or long-term (chronic) studies.

This effluent hazard evaluation is considered a valuable screening technique because effluent concentrations that are several orders of magnitude above water quality objectives may have serious environmental impacts. Potential impacts may include harmful effects to aquatic life, loss of fish habitat, loss of beneficial uses of aquatic resources (*e.g.*, recreation and water supplies), and increased costs for remediation.

This approach is consistent with the pollution prevention philosophy of the Ministry of Environment and Energy and with the commitments made by the Province of

Ontario under the Great Lakes Water Quality Agreement. Also, discharging substances in highly toxic amounts will be prohibited in MISA Effluent Limit Regulations. A substance was considered to be discharged in highly toxic amounts if it entered the environment in a quantity or concentration that has an immediate or long-term harmful effect on aquatic organisms.

## 3.1 Results

The frequencies of exceedences of the various assessment endpoints (e.g., PWQO times 10) are summarized in Table 2.3. The frequencies computed for each sector were based on at least 10 observations. Comments on selected contaminants are provided below.

### 3.1.1 Cadmium

Cadmium is ubiquitous in municipal and industrial sector effluents. The pulp and paper, mining, iron and steel, inorganic chemicals, and metal casting sectors exhibited effluent concentrations above 20 µg/L (i.e., 100 times the PWQO). The petroleum, industrial minerals, and municipal sectors exhibited effluent concentrations above 5 µg/L (Table 2.3). Concentrations of cadmium in water at or above 5 µg/L are highly toxic to aquatic life during short or long-term water-borne exposures (GLWQI, 1991; OMOE, 1979; Biesinger and Christensen, 1972).

### 3.1.2 Chlordane

Alpha- and gamma-chlordane were occasionally found in municipal discharges, although concentrations did not exceed 0.08 µg/L (Table 2.3). Discharges of chlordane at or above 2 µg/L are considered to be highly toxic to aquatic biota based on chronic toxicity data for waterborne exposures (GLWQI, 1991; U.S. EPA, 1980; OMOE, 1979).

### 3.1.3 1,4-Dichlorobenzene (1,4-DCB)

Concentrations of 1,4-dichlorobenzene found in effluents from the organic chemical manufacturing sector (OCM) and the inorganic chemicals sector were less than 40 µg/L or 10 times the PWQO (Table 2.3). Therefore, analysis of MISA effluents did not reveal the existence of highly toxic discharges of 1,4-DCB. 1,4-DCB is highly toxic to aquatic life when ambient concentrations exceed 2000 µg/L in short-term exposures or 400 µg/L in long-term exposures (OMOE, 1984).

## TABLE 2.3 SUMMARY OF MISA EFFLUENT DISCHARGE DATA AND FREQUENCY OF EXCEEDANCES OF VARIOUS HAZARD ASSESSMENT END-POINTS

| ANALYTICAL PARAMETER | ASSESSMENT END-POINT | CONCENTRATION (ug/L) | ORGANIC CHEMICAL | IRON & STEEL | INORGANIC CHEMICAL | PETROLEUM | PULP & PAPER | MINING | METAL CASTING | MUNICIPAL WPCPs |
|---|---|---|---|---|---|---|---|---|---|---|
| CADMIUM | 10 x PWQO | 2 | | ++ | +++ | ++ | ++ | ++ | +++ | ++ |
| | 100 x PWQO | 20 | | + | ++ | | ++ | + | + | |
| | 1000 x PWQO | 200 | | | | | | | | |
| | 10000 x PWQO | 2000 | | | | | | | | |
| CHLORDANE (TOTAL) | 10 x PWQO | 0.6 | | | | | | | | |
| | 100 x PWQO | 6 | | | | | | | | |
| | 1000 x PWQO | 60 | | | | | | | | |
| | 10000 x PWQO | 600 | | | | | | | | |
| 1,4-DICHLOROBENZENE | 10 x PWQO | 40 | | | | | | | | |
| | 100 x PWQO | 400 | | | | | | | | |
| | 1000 x PWQO | 4000 | | | | | | | | |
| | 10000 x PWQO | 40000 | | | | | | | | |
| ENDOSULFAN (TOTAL) | 10 x PWQO | 0.03 | | | | | | | | |
| | 100 x PWQO | 0.3 | | | | | | | | |
| | 1000 x PWQO | 3 | | | | | | | | |
| | 10000 x PWQO | 30 | | | | | | | | |
| HEXACHLOROBENZENE | 10 x PWQO | 0.065 | + | | ++ | | | | | |
| | 100 x PWQO | 0.65 | | | ++ | | | | | |
| | 1000 x PWQO | 6.5 | | | + | | | | | |
| | 10000 x PWQO | 65 | | | | | | | | |
| alpha-HEXACHLOROCYCLOHEXANE | 10 x NYSDEC | 0.1 | | | | | | | | |
| | 100 x NYSDEC | 1 | | | | | | | | |
| | 1000 x NYSDEC | 10 | | | | | | | | |
| | 10000 x NYSDEC | 100 | | | | | | | | |
| gamma-HEXACHLOROCYCLOHEXANE | 10 x PWQO | 0.1 | | | | | | | | |
| | 100 x PWQO | 1 | | | | | | | | |
| | 1000 x PWQO | 10 | | | | | | | | |
| | 10000 x PWQO | 100 | | | | | | | | |
| MERCURY | 10 x PWQO | 2 | +++ | | +++ | | | +++ | ++ | |
| | 100 x PWQO | 20 | + | | ++ | | | +++ | | |
| | 1000 x PWQO | 200 | | | + | | | ++ | | |
| | 10000 x PWQO | 2000 | | | | | | | | |

/cont'd...

| ANALYTICAL PARAMETER | ASSESSMENT END-POINT | CONCENTRATION (ug/L) | ORGANIC CHEMICAL | IRON & STEEL | INORGANIC CHEMICAL | PETROLEUM | PULP & PAPER | MINING | METAL CASTING | MUNICIPAL WPCPs |
|---|---|---|---|---|---|---|---|---|---|---|
| PAH/ BENZO[A]PYRENE | 100 x GLWQA | 1 | | ++ | | | | | | |
| | 1000 x GLWQA | 10 | | | | | | | | |
| | 10000 x GLWQA | 100 | | | | | | | | |
| PCB (TOTAL) | 100 x PWQO | 0.1 | + | | ++ | | | | | |
| | 1000 x PWQO | 1 | | | + | | | | | |
| | 10000 x PWQO | 10 | | | | | | | | |
| PCDD-F/ 2,3,7,8-TCDD | 10000 x PWQG | 0.0002 | | | | | ++ | | | |
| PCDD-F/ TOTAL TCDD | 10000 x PWQG | 0.0002 | + | | + | | +++ | | | |
| PCDD-F/ TOTAL TCDF | 100 x PWQG | 0.00002 | ++ | | ++ | +++ | ++ | | | |
| | 1000 x PWQG | 0.0002 | | | ++ | +++ | ++ | | | |
| | 10000 x PWQG | 0.002 | | | + | | | | | |
| PENTACHLOROPHENOL | 10 x PWQO | 5 | | | | | | | | |
| | 100 x PWQO | 50 | | | | | | | | |
| | 1000 x PWQO | 500 | | | | | | | | |
| | 10000 x PWQO | 5000 | | | | | | | | |

NOTES: PWQO = Ontario Provincial Water Quality Objective
PWQG = Ontario Provincial Water Quality Guideline
NYSDEC = New York State ambient water quality criterion
GLWQA = Great Lakes Water Quality Agreement criterion
+ = 1 - 4% of samples exceeded specified criteria
++ = 5 - 24% of samples exceeded specified criteria
+++ = >25% of samples exceeded specified criteria
Information supplied by MISA Data Management and Municipal Sections

### 3.1.4 Endosulfan

Alpha- and beta-endosulfan and endosulfan-sulphate were occasionally found in municipal discharges at low concentrations (Table 2.3). The maximum concentrations ranged from 0.02 to 0.17 µg/L. Discharges of endosulfan at 0.3 µg/L are considered to be highly toxic to aquatic biota based on acute toxicity data for waterborne exposures (Devi *et al.*, 1981; OMOE, 1979).

### 3.1.5 Hexachlorobenzene (HCB)

Concentrations of hexachlorobenzene exceeded the PWQO by 100 times or more in effluents from the inorganic chemicals sector (Table 2.3). The maximum concentration found was 5 µg/L. At this upper level, HCB in water is not considered to be highly toxic to aquatic biota during acute or chronic water-borne exposures (U.S. EPA, 1988; OMOE, 1984).

### 3.1.6 Alpha-Hexachlorocyclohexane (Alpha-BHC)

Alpha-BHC was occasionally found in municipal discharges and concentrations did not exceed 0.05 µg/L (Table 2.3). Discharges of alpha-BHC at 100 µg/L are considered to be highly toxic to aquatic biota based on chronic toxicity data for waterborne exposures (Canton *et al.*, 1975; Canton and Slooff, 1977).

### 3.1.7 Gamma-Hexachlorocyclohexane (Lindane)

Lindane was often found in municipal discharges, however, concentrations did not exceed 0.1 µg/L (Table 2.3). Discharges of lindane at 0.3 µg/L are considered to be highly toxic to aquatic biota based on acute toxicity data for waterborne exposures (Sanders, 1972).

### 3.1.8 Mercury

Mercury is ubiquitous in industrial and municipal sector effluents. The OCM, pulp and paper, and metal casting sectors exhibited effluent concentrations of 2 µg/L or more and the mining and inorganic sectors exhibited effluent concentrations above 200 µg/L (Table 2.3). Concentrations of mercury in water at or above 2 µg/L (i.e., 10 times the PWQO) are highly toxic to aquatic life during short-term and long-term water-borne exposures (Eisler, 1987).

### 3.1.9 Pentachlorophenol (PCP)

Pentachlorophenol concentrations of less than 10 times the PWQO were detected in the pulp and paper sector (Table 2.3). The highest concentration found was approximately 3 µg/L. At this upper level, PCP is highly toxic to aquatic biota based on chronic toxicity data for water-borne exposures (Eisler, 1989; OMOE, 1984a).

### 3.1.10 Polychlorinated Biphenyl (PCB)

PCB concentrations in effluents from the organic chemicals manufacturing, metal casting, and municipal sectors did not exceed 0.2 µg/l. However, concentrations of PCBs in some discharges from the inorganic chemicals sector exceeded the Provincial Water Quality Objective of 0.001 µg/L by 1000 times or more in a small percentage of samples (Table 2.3). At 1 µg/L, industrial waste streams are considered to be highly toxic to aquatic biota based on acute and chronic PCB toxicity data for water-borne exposures (Eisler, 1986; OMOE, 1979; Birge *et al.*, 1978).

### 3.1.11 Polychlorinated Dibenzo-p-dioxins and Dibenzofurans (PCDD-Fs)

Polychlorinated dibenzo-p-dioxins or polychlorinated dibenzofurans were detected in effluents from the organic, inorganic, and pulp and paper sectors at levels greater than 10,000 times the PWQGs for 2,3,7,8-tetrachlorodibenzo-p-dioxin and 2,3,7,8-tetrachlorodibenzofuran (Table 2.3). At these levels, industrial effluents are considered to be highly toxic to aquatic life based on acute and chronic toxicity data for 2,3,7,8-TCDD and chronic toxicity data for 2,3,7,8-TCDF (Mehrle *et al.*, 1988; Eisler, 1986a).

A hazard evaluation of other dioxins or furans found in effluents from the OCM, iron and steel, inorganic, pulp and paper, and petroleum sectors was not undertaken because of limited available water quality criteria and toxicity information.

### 3.1.12 Polycyclic Aromatic Hydrocarbon (PAHs)

Benzo[*a*]pyrene concentrations in industrial effluent were found to exceed 1 µg/L in the iron and steel sector (Table 2.3). Moreover, waste streams containing 1 µg/L of benzo[*a*]pyrene are considered to be highly toxic to aquatic life based on acute and chronic toxicity data (Oris and Giesy, 1987; Newsted and Giesy, 1987; Hose *et al.*, 1984; Hannah *et al.*, 1982).

Since water quality criteria were not available for anthracene, benz[*a*]anthracene, benzo[*g,h,i*]perylene, perylene, and phenanthrene, a complete hazard evaluation of these PAH compounds found in effluents from the iron and steel, pulp and paper, metal casting, or the inorganic sectors was not undertaken. However, concentrations of these compounds in discharged effluents are not believed to be highly toxic to aquatic biota based on available monitoring information.

### 3.2 Summary of Hazard Assessment

The environmental risk characterization of MISA effluents clearly extended the hazard identification and loadings information presented earlier in this report. Some sectors are discharging highly hazardous substances, such as benzo[*a*]pyrene (iron and steel sector), cadmium (mining, inorganic chemicals, metal casting, iron and steel, petroleum, pulp and paper, industrial minerals and municipal sectors), mercury (organic chemical manufacturing, inorganic chemicals, mining, metal casting, and pulp and paper sectors), polychlorinated biphenyls (organic and inorganic chemicals sectors) and polychlorinated dibenzo-p-dioxins (organic, inorganic, and pulp and paper sectors) at high concentrations that can exert toxic effects on aquatic organisms exposed directly to contaminated water for short periods of time (*e.g.*, less than 96 hours).

Certain sectors are also discharging pentachlorophenol (pulp and paper sector) and polychlorinated dibenzofurans (organic, inorganic, and pulp and paper sectors) at low concentrations that can exert toxic effects on organisms in the immediate vicinity of point source discharges under chronic conditions.

Discharges of hexachlorobenzene (inorganic sector), mercury (inorganic and mining sectors), PCB (inorganic sector), and polychlorinated dibenzo-p-dioxins or dibenzofurans (organic, inorganic, petroleum, and pulp and paper sectors) at times exceeded concentrations corresponding to 1000 times the Provincial Water Quality Objectives or GLWQA specific objectives (Table 2.3). Also, discharges of cadmium from the iron and steel, inorganic, pulp and paper, and metal casting sectors at times exceeded concentrations corresponding to 100 times the PWQO. These results indicate an increased risk or likelihood for impairments of the aquatic environment, particularly in the vicinity of point source discharges.

## 4 Use Impairments / Receiving Water Impacts

The toxics problem in the Ontario Great Lakes watershed can be characterized using a chemical-specific approach to identify impairments or losses of beneficial uses of aquatic resources. This approach is considered very useful and practical for identifying impacts of hazardous substances and determining appropriate remedial actions in the context of existing law and regulation.

In order to identify impairments of beneficial uses in the Ontario Great Lakes ecosystem, all available environmental quality data were compared to existing objectives, guidelines, or criteria (Table 2.4). The beneficial use impairments considered were: restrictions on fish and wildlife consumption; restrictions on dredging activities; restrictions on drinking water consumption; and impairments or degradation of water and sediment quality for supporting aquatic life.

The environmental data sets reviewed in this project included the Remedial Action Plan (RAP) stage 1 reports for 17 Areas of Concern located in Ontario, and all available monitoring studies conducted by the Ontario Ministry of the Environment, Environment Canada, and other agencies or research groups. Some of the important

## TABLE 2.4 AMBIENT WATER, DRINKING WATER, SEDIMENT & BIOTA CRITERIA USED FOR COMPARISONS

| | AMBIENT WATER | DRINKING WATER | PROVINCIAL SEDIMENT QUALITY GUIDELINES | | BIOTA CRITERIA | | | |
|---|---|---|---|---|---|---|---|---|
| PARAMETER | PWQO/G (ng/L) | ODWO (ng/L) | LOWEST EFFECT LEVEL (mg/kg) | SEVERE EFFECT LEVEL (mg/kg) | NYSDEC (mg/kg) | IJC* (mg/kg) | HWC (mg/kg) | U.S. FDA (mg/kg) |
| ALDRIN | 1 | 700 | 0.002 | 8** | | 0.3 | | |
| CADMIUM | 200 | 5000 | 0.6 | 10 | | | | |
| CHLORDANE (TOTAL) | 60 | 7000 | 0.007 | 6** | | | | 0.3 |
| DDT & METABOLITES | 3 | 30000 | 0.007*** | 12*** | | 1 | | |
| 1,4-DICHLOROBENZENE | 4000 | 1000 | | | | | | |
| DIELDRIN | 1 | 700 | 0.002 | 91 | | 0.3 | | |
| ENDOSULFAN (TOTAL) | 3 | 74000 a | | | | | | |
| ENDRIN | 2 | 200 b | 0.003 | 130* | | 0.3 | | |
| HEPTACHLOR (TOTAL) | 1 | 3000 | 0.005 | 5** | | 0.3 | | |
| HEXACHLOROBENZENE | 6.5 | 10 c | 0.02 | 24** | 0.33 | | | |
| ALPHA-HEXACHLOROCYCLOHEXANE | 10 e | | 0.006 | 10** | 0.1 | | | |
| GAMMA-HEXACHLOROCYCLOHEXANE (LINDANE) | 10 | 4000 | 0.003 | 1** | 0.1 | 0.3 | | |
| MERCURY | 200 | 1000 | 0.2 | 2 | | 0.5 | 0.5 | |
| MIREX | 1 | | 0.007 | 130 | | <D.L. | | |
| PAH/ BENZO[A]PYRENE | 10 d | 10 | 1.0 d | | | 1 | | |
| PAH (TOTAL) | | | 2 | 11000** | | | | |
| PCB (TOTAL) | 1 | 3000 | 0.07 | 530** | 0.11 | 0.1 | 2 | |
| PENTACHLOROPHENOL | 500 | 30000 | | | 2 | | | |
| 2,3,7,8 TCDD (or TOTAL TCDD) | 0.00002 | 15 pg/L | | | 3 pg/g | | 0.00002 | |
| 2,3,7,8 TCDF (or TOTAL TCDF) | 0.0002 | 15 pg/L | | | | | | |
| TOXAPHENE | 8 | 5000 | | | | | | |
| TRIFLURALIN | 100 f | 45000 | | | | | | |

NOTES:

* GLWQA/MOE Specific Objective

** These values to be normalized to the actual TOC measured in sediment

*** For total DDT (see other values for DDE, DDD, etc.)

D.L. = Detection Limit

a = U.S. EPA human health criterion

b = U.S. EPA maximum acceptable concentration

c = World Health Organisation guideline

d = IJC guideline

e = New York State Dept. of Environment & Conservation

f = Canadian Water Quality Guideline (aquatic life)

Ministry programs contributing information to this project included the Sports Fish Monitoring Program, the Spottail Shiner Biomonitoring Program, the Great Lakes Surveillance Program, the Provincial Water Quality Monitoring Network, the In-Place Pollutants Program, the Drinking Water Surveillance Program and other studies or monitoring programs concerned with contaminants in effluents, ambient water, ground water, sediments, suspended sediments, and biota. A listing of the information sources reviewed is found in Appendix 'C'.

The assessment of use impairments in the Great Lakes basin encompasses a comprehensive ecosystem approach for defining environmental health in terms of viability and sustainability. The criteria selected for defining impairments take into account important socio-economic and ecosystem-level attributes necessary for maintenance of the system's health.

This approach integrates the complex interrelationships among terrestrial and aquatic ecosystems because air, land, or water releases of highly bioaccumulative and persistent compounds ultimately accumulate or bioconcentrate in aquatic ecosystems. Aquatic ecosystems are sensitive to inputs of highly hazardous substances and to changes to the integrity of the biosphere. Furthermore, the majority of Ontario's people and industries are located in the Great Lakes basin and depend on aquatic resources for food, water, recreation, transportation and many other uses.

The evaluation of receiving water impacts is summarized in the following section and in Table 2.5. A detailed discussion on which these comments are based is presented in Appendix 'B'.

## 4.1 Aldrin

Concentrations of aldrin exceeded the PWQO of 1 ng/L for the protection of aquatic life in nearshore areas of Lake Ontario such as Toronto Harbour and in the Don River. Concentrations of aldrin adsorbed to bottom sediments exceeded the Provincial Sediment Quality Guideline (lowest effect level) in Areas of Concern such as Thunder Bay, Collingwood Harbour, and the St. Lawrence River. Aldrin has also been detected in benthic invertebrates (up to 0.032 mg/kg, wet weight) in Toronto Harbour. Levels in fish are not detectable or they are less than the GLWQA objective of 0.3 mg/kg for the protection of human consumers of fish. These results indicate impaired water and sediment conditions for supporting aquatic life and restrictions on dredging activities (i.e., open water disposal of dredged sediments).

## 4.2 Cadmium

Receiving water impacts, such as impaired water or sediment quality and restrictions on dredging activities exist in several Areas of Concern and rivers located throughout the Great Lakes ecosystem. Exceedences of the Provincial Sediment Quality Guidelines (severe effect level and lowest effect level) and PWQO indicate a widespread concern for aquatic toxicity and loss of fish or invertebrate habitat.

# TABLE 2.5 USE IMPAIRMENTS* IDENTIFIED IN THE ONTARIO GREAT LAKES BASIN

| PARAMETER | Lake Superior | St. Mary's River System | Lake Huron | St. Clair/Detroit River System | Lake Erie | Niagara River | Lake Ontario | St. Lawrence River | Inland Lakes & Rivers |
|---|---|---|---|---|---|---|---|---|---|
| aldrin | S | | | | | | W | S | W S |
| cadmium | W S | S | W S | W S | S | W S | W S | S | W S |
| chlordane (total) | S | S | S | S | S | | S | S | S |
| DDT & metabolites | W S | S | S | W S | S | S | W S | S | W S |
| 1,4-dichlorobenzene | | | | | | | | | |
| 3,3'-dichlorobenzidine | | | | | | | | | |
| dieldrin | S | S | S | S | | S | W S | S | |
| endosulfan (total) | W | | | W | | | W | | W |
| endrin | S | S | S | | | S | S | S | S |
| heptachlor (total) | W S | S | S | W | | | W S | S | W S |
| hexachlorobenzene | W S | | S | W S | | S | W S | S | |
| alpha-hexachlorocyclohexane | W | | | S | | | S | | |
| gamma-hexachlorocyclohexane | | | S | W S | | | W | | W S |
| mercury | W S B | W S B | S B | W S B | W S B | S B | W S B | S B | S B |
| mirex | | | | | | S B | S B | B | |
| PAH/ anthracene | S | S | | S | | | S | S | |
| PAH/ benzo[g,h,i]perylene | | S | | | | | S | | S |
| PAH/ benzo[a]pyrene | S | S | | S | | S | S | S | S |
| PAH/ benz[a]anthracene | S | S | | S | | | S | S | S |
| PAH/ perylene | | S | | | | | | | |
| PAH/ phenanthrene | | S | | S | | | S | S | S |
| PCB (total) | W S B | S | W S B | W S B | W S B | W S B | W S B | W S B | W S B |
| pentachlorophenol | | | | | | | W | | W |
| polychlorinated dioxins & furans | B | | | | | B | B | | |
| toxaphene | | | | | | | | | |
| tributyltin | | | | | | | | | |
| trifluralin | | | | | | | | | |

NOTES: * = Defined as an exceedence of a water quality criterion, sediment quality criterion, or sport fish or other biota criterion.
W = water; S = sediment; B = biota

### 4.3 Chlordane

Chlordane compounds (alpha and gamma isomers and oxychlordane) are ubiquitous in the Great Lakes ecosystem. There is increased risk for aquatic toxicity and loss of fish and invertebrate habitat in Thunder Bay, Peninsula Harbour, the St. Marys River, Detroit River, Collingwood Harbour, Hamilton Harbour, Toronto Harbour and waterfront, and the St. Lawrence River based on exceedences of the Provincial Sediment Quality Guideline (PSQG) (lowest effect level). Also, open water disposal of contaminated dredgeate would be restricted.

Concentrations found in water are less than the Provincial Water Quality Objective of 60 ng/l (total chlordane). In addition, the elevated concentrations found in fish do not exceed the NYSDEC (New York State Department of Environmental Conservation) criterion of 0.5 mg/kg for the protection of piscivorous wildlife and the U.S. Food and Drug Administration guideline of 0.3 mg/kg for the protection of humans.

### 4.4 DDT and metabolites (DDE, DDD)

DDT or its degradation products have caused impairments of water and sediment quality in many areas of Ontario. Moreover, exceedences of the PWQO and Provincial Sediment Quality Guidelines (lowest and severe effect levels) indicate a widespread concern for aquatic toxicity, loss of fish or invertebrate habitat, and restrictions on dredging activities.

### 4.5 1,4-Dichlorobenzene (1,4-DCB)

Although beneficial use impairments based on available criteria have not been reported in the aquatic environment, elevated concentrations of 1,4-DCB are found in open waters throughout the Great Lakes ecosystem. However, concentrations are generally less than 5 ng/L or well below the PWQO. Also, elevated levels in biota and sediments have been found in areas receiving industrial inputs.

### 4.6 3,3'-Dichlorobenzidine

Receiving water impacts of 3,3'-dichlorobenzidine have not been reported in the Ontario Great Lakes basin.

### 4.7 Dieldrin

Concentrations of dieldrin have exceeded the PWQO of 1 ng/L for the protection of aquatic life in nearshore areas of Lake Ontario such as Port Weller Harbour and Toronto Harbour. Concentrations of dieldrin adsorbed to bottom sediments have exceeded the Provincial Sediment Quality Guideline (lowest effect level) in Areas of Concern such as Peninsula Harbour, St. Marys River, Penetang Harbour,

Collingwood Harbour, St. Clair River, Niagara River, Hamilton Harbour, Toronto Harbour, Bay of Quinte, and the St. Lawrence River.

### 4.8 Endosulfan

Endosulfan compounds (alpha and beta isomers and endosulfan sulphate) have been detected in water, sediment, or biota in several watersheds and Areas of Concern including Thunder Bay, Peninsula Harbour, St. Marys River, Collingwood Harbour, St. Clair River, Detroit River, Canagagigue Creek, Toronto Harbour and waterfront, Oakville Harbour, Rice Lake, Bay of Quinte, and the St. Lawrence River. Water concentrations have occasionally exceeded the Provincial Water Quality Objective of 3 ng/L. There is currently no provincial criterion for safe concentrations of endosulfan in sediments or fish.

### 4.9 Endrin

Endrin, like chlordane, has caused beneficial use impairments such as restrictions on dredging activities and impairments of sediment quality throughout the Great Lakes basin based on exceedences of the Provincial Sediment Quality Guideline (lowest effect level). Concentrations found in surface waters were less than the PWQO of 2 ng/L.

### 4.10 Heptachlor

Heptachlor and its degradation product, heptachlor epoxide, have caused impairments of water and sediment quality in many areas of Ontario. Moreover, exceedences of the PWQO and Provincial Sediment Quality Guideline (lowest effect level) indicate a widespread concern for aquatic toxicity and loss of fish or invertebrate habitat. Also, open water disposal of contaminated dredgeate would be restricted. Presently, there are no restrictions on human consumption of sport fish because of heptachlor levels.

### 4.11 Hexachlorobenzene (HCB)

Receiving water impacts, such as impaired sediment and water quality conditions and elevated concentrations of HCB in invertebrates, caged mussels, fish, waterfowl, and snapping turtle eggs, have been found in areas receiving industrial inputs. There is increased risk for aquatic toxicity and loss of fish and invertebrate habitat in the St. Clair River and the St. Lawrence River based on exceedences of the Provincial Sediment Quality Guidelines (PSQG) (severe effect level and lowest effect level) and the Provincial Water Quality Objective. In addition, exceedences of the PSQG (lowest effect level) have been found in the Niagara River, Detroit River, Peninsula Harbour, Collingwood Harbour, and the Bay of Quinte.

### 4.12 Alpha-Hexachlorocyclohexane

The alpha isomer of hexachlorocyclohexane (also known as alpha-BHC or alpha-HCH) is ubiquitous in the Great Lakes ecosystem. Elevated concentrations have been found in water, sediments, and biota. Exceedence of the NYSDEC (New York State Department of Environmental Conservation) ambient water quality criterion of 10 ng/l for the protection of aquatic life was found in Peninsula Harbour. Sediment conditions considered harmful to aquatic life were found in the St. Clair River and Hamilton Harbour.

### 4.13 Gamma-Hexachlorocyclohexane

This substance (also known as gamma-BHC, gamma-HCH or Lindane) has been detected in water, sediment or biota samples from several Areas of Concern and tributaries throughout the Great Lakes basin. Impairments or degradation of ambient water quality for supporting aquatic life were found at 13 of 66 river and stream monitoring sites and in Hamilton Harbour and Toronto Harbour. In addition, restrictions on dredging activities and impairments of sediment quality for supporting aquatic life were found in Collingwood Harbour, the St. Clair River, Canagagigue Creek, and Rice Lake based on exceedence of the 'lowest effect level' sediment quality guideline.

### 4.14 Mercury

Mercury has caused beneficial use impairments throughout the Great Lakes ecosystem. These impairments include restrictions on fish consumption by humans and wildlife, restrictions on dredging activities, and impairments of water and sediment quality based on exceedences of available criteria. Exceedences of the GLWQA specific objective for biota of 0.5 mg/kg indicate a widespread concern for behavioural effects in fish-consuming birds.

### 4.15 Mirex

Mirex is the contaminant mainly responsible for restrictions on human consumption of Lake Ontario sport fish. Although significant declines have occurred in recent years, mirex concentrations in fish from some locations in the western end of the lake, such as the Credit River, continue to be elevated. Also, mirex levels in fish from the St. Lawrence River near Cornwall exceeded the Health and Welfare Canada guideline of 0.1 mg/kg and resulted in consumption advisories for protecting human health.

Mirex was detected in forage fish from some Niagara River, Lake Ontario and St. Lawrence River collection sites and, therefore, exceeded the GLWQA specific objective of 'non-detectable' for protecting birds and animals that consume fish.

Exceedences of the Provincial Sediment Quality Guideline (PSQG) (lowest effect level) in the Niagara River, Lake Ontario, and the St. Lawrence River indicate toxic conditions, a loss of fish and invertebrate habitat, and restrictions on dredging activities.

### 4.16 Pentachlorophenol (PCP)

Pentachlorophenol has been detected in water, sediment, and biota in Areas of Concern such as Thunder Bay, Toronto Harbour, Bay of Quinte, and the St. Lawrence River. Water concentrations have occasionally exceeded the Provincial Water Quality Objective of 500 ng/L. These exceedences tend to be localized in the vicinity of continuous inputs, predominantly from wood preserving plants and to a lesser extent from pulp and paper mills.

### 4.17 Polychlorinated Biphenyls (PCBs)

PCBs, like mercury, have caused beneficial use impairments such as restrictions on fish consumption by humans and wildlife, restrictions on dredging activities, and impairments of sediment and ambient water quality throughout the Great Lakes watershed.

The exceedences of the Provincial Sediment Quality Guideline (lowest effect level), the GLWQA specific objective for whole fish, and the New York State Department of Environmental Conservation biota criterion in Areas of Concern indicate a widespread potential for aquatic toxicity and reproductive toxicity or cancer in birds and mammals that consume contaminated fish. However, actual occurrence of effects depends on the extent and duration to which animals consume fish with residues in excess of 0.1 mg/kg.

### 4.18 Polychlorinated Dibenzo-p-dioxins and Dibenzofurans (PCDD-Fs)

Restrictions on the consumption of sport fish, based on levels of 2,3,7,8-TCDD (or toxic equivalents), exist in the Niagara River, Lake Ontario, and Lake Superior. Furthermore, elevated levels of dioxins and furans in water, sediment, caged mussels, forage fish, sport fish, herring gull eggs and snapping turtle eggs have been detected in areas receiving industrial inputs. These results suggest an increased risk of reproductive effects or cancer in wildlife that consume contaminated fish.

### 4.19 Polycyclic Aromatic Hydrocarbons (PAHs)

Elevated concentrations of PAH compounds, particularly benzo[*a*]pyrene, phenanthrene, benz[*a*]anthracene, anthracene, perylene, and benzo[*g,h,i*]perylene, have been detected in water, sediment, aquatic invertebrates, caged mussels, fish, or waterfowl eggs in Areas of Concern such as the St. Mary's River, St. Clair River, Detroit River, Niagara River, Hamilton Harbour, Bay of Quinte, and the St. Lawrence

River. Moreover, sediment concentrations of each of these compounds exceeded the Provincial Sediment Quality Guideline (lowest effect level) for total PAH compounds. These results indicate that open water disposal of dredged materials would be restricted and there is an increased risk for aquatic toxicity and loss of fish and invertebrate habitat. Also, exceedences of the International Joint Commission sediment quality objective of 1 mg/kg for benzo[*a*]pyrene in Thunder Bay Harbour, the St. Mary's River, Niagara River, and Hamilton Harbour indicate a widespread concern for tumour induction in fish.

### 4.20 Toxaphene

Although beneficial use impairments based on available criteria have not been reported, concentrations of less than 2 ng/L or below the PWQO are found in open waters throughout the Great Lakes ecosystem. Toxaphene has also been detected in Ontario sport fish at levels below 3 mg/kg. Presently, there are no restrictions on human consumption of sport fish because of toxaphene levels.

### 4.21 Tributytin

There is limited information available to assess beneficial use impairments caused by tributyltin. However, based on findings from the Severn Sound Area of Concern, Whitby Harbour, and Oshawa Harbour, elevated concentrations in water, sediments, or biota may occur near marinas from releases of tributyltin oxide used as an active ingredient in antifoulant paints applied to boat hulls. Also, inputs from industrial activities may cause elevated concentrations particularly in the St. Clair and Detroit Rivers.

### 4.22 Trifluralin

There is no information available to assess beneficial use impairments caused by trifluralin.

## 5 Summary of Ontario-Specific Data Evaluation

The Primary List was screened against a variety of Ontario-specific supporting information concerning:

- presence and loadings from industrial and municipal point sources discharging directly into Ontario surface waters;
- toxicity and potential hazards of MISA industrial and municipal effluents; and
- Ontario receiving water impacts.

In general, these evaluations support the position that the primary substances should be retained on a short list of candidate substances for bans, phase-outs and reductions from industrial and municipal point sources. The basis for this position is summarized below.

### 5.1 Point Source Loadings

The available loadings information indicate there are significant industrial or municipal point source inputs of seventeen hazardous substances to the aquatic environment, particularly cadmium, 1,4-dichlorobenzene, hexachlorobenzene, lindane, mercury, pentachlorophenol, polychlorinated biphenyls and polycyclic aromatic hydrocarbons. Direct municipal inputs of chlordane and endosulfan compounds were estimated to be 2 and 3 kg/year, respectively. In addition, industrial discharges of polychlorinated dibenzo-p-dioxins or dibenzofurans and municipal discharges of alpha-BHC were not greater than 1 kg per year.

### 5.2 Environmental Hazards of Point Source Discharges

Several highly hazardous substances are being discharged at high concentrations considered to be acutely toxic to aquatic organisms. These include cadmium, mercury, PCBs, polychlorinated dibenzo-p-dioxins and benzo[*a*]pyrene. Furthermore, some industrial sectors are discharging pentachlorophenol and polychlorinated dibenzofurans at low concentrations considered to be toxic to aquatic organisms when exposed to contaminated water for a major part of their lifespan.

Discharges of hexachlorobenzene, mercury, PCBs and polychlorinated dibenzo-p-dioxins or -furans at times exceeded concentrations corresponding to 1000 times the Provincial Water Quality Objectives or GLWQA specific objectives. Also, discharges of cadmium at times exceeded concentrations corresponding to 100 times the PWQO. These findings indicate an increased risk of serious environmental impacts including sediment accumulation and bioconcentration of persistent toxic substances, impaired fish habitat, loss of beneficial uses of aquatic resources, and increased costs for remediation in the vicinity of point source discharges.

## 5.3 Receiving Water Impacts

Receiving water impacts in Ontario were found for all candidate substances except 3,3'-dichlorobenzidine and trifluralin. The environmental impacts included elevated concentrations (*i.e.*, above background levels) found in water, sediment, or biota in areas receiving anthropogenic inputs and use impairments based on exceedences of available criteria.

Widespread use impairments were identified for all Primary List substances except 1,4-dichlorobenzene, 3,3'-dichlorobenzidine, toxaphene, tributyltin and trifluralin. 1,4-dichlorobenzene was not detected at levels exceeding established criteria. Use impairments could not be determined for 3,3'-dichlorobenzidine and tributyltin because no water, sediment or biota criteria were available for these substances. No monitoring data were available for trifluralin.

Impairments of water quality for supporting aquatic life were found for aldrin, cadmium, DDT and metabolites, dieldrin, endosulfan, heptachlor, hexachlorobenzene, alpha-hexachlorocyclohexane, gamma-hexachlorocyclohexane (lindane), mercury, pentachlorophenol and PCBs. Also, impairments of sediment quality for supporting aquatic life were found for aldrin, cadmium, chlordane, DDT and metabolites, dieldrin, endrin, hexachlorobenzene, alpha-hexachlorocyclohexane, gamma-hexachlorocyclohexane, heptachlor, mercury, mirex, PCBs, anthracene, benz[*a*]anthracene, benzo[*a*]pyrene, benzo[*g,h,i*]perylene, perylene, and phenanthrene. Restrictions on dredging activities (*i.e.*, open water disposal of contaminated sediments) were found for aldrin, cadmium, chlordane, DDT + metabolites, dieldrin, endrin, heptachlor, hexachlorobenzene, alpha-hexachlorocyclohexane, gamma-hexachlorocyclohexane, mercury, mirex, PCBs, anthracene, benz[*a*]anthracene, benzo[*a*]pyrene, benzo[*g,h,i*]perylene, perylene, and phenanthrene.

Restrictions or limitations on the safe consumption of fish by humans and wildlife were found for mercury, mirex, PCBs, and 2,3,7,8-TCDD. However, no restrictions on drinking water supplies for human consumption were found for any of the substances on the Primary List.

# Conclusions

- Of over 1000 substances and groups of substances assessed, 27 have been designated as being the most inherently hazardous to environmental health due to their persistence, bioaccumulation potential and toxicity. These substances appear on the Revised Primary List of Candidate Substances for Bans, Phase-Outs or Reductions. Seven substances appear on the revised list which did not appear on the original Primary List published in April 1992. The additional substances are aldrin, cadmium, chlordane, endosulfan, endrin, heptachlor and trifluralin.

- It has been demonstrated that twenty-two of the Primary List substances have caused impairments of beneficial uses of water, sediment or biota in Ontario. Of the remaining five substances, 1,4-dichlorobenzene and toxaphene have not been detected at levels which exceed established criteria, 3,3'-dichlorobenzidine and tributyl tin could not be evaluated from a receiving water/sediment/biota impaired use perspective because no appropriate criteria have been established for these substances, and no data were available for trifluralin.

- Twenty-four of the 27 Primary List substances were monitored under MISA or in the 1987 Municipal Water Pollution Control Plants Study. Analysis of the monitoring data has demonstrated that 13 substances are being directly discharged to surface water by Ontario-based industrial point sources and that 7 substances are being directly discharged by Ontario municipal water pollution control plants. Overall, 17 Primary List substances were found to be discharged to surface waters by Ontario-based point sources. The substances not found to be discharged are aldrin, DDT (and its metabolites), dieldrin, endrin, heptachlor, mirex and toxaphene. Effluent monitoring data were not available for 3,3'-dichlorobenzidine, tributyl tin and trifluralin.

- Five Primary List substances are being discharged to Ontario surface waters at levels considered to be acutely toxic to aquatic biota. These were cadmium, mercury, PCBs, polychlorinated dibenzo-p-dioxins and benzo[*a*]pyrene.

- An additional 63 substances were designated as being toxic and either persistent or bioaccumulative, or as being persistent and/or bioaccumulative but somewhat less toxic than those on the Primary List. These substances appear on the Secondary List, recommended as a "second tier" of candidate substances for action.

# Appendix 'A' - Lists of Candidate Substances for Bans, Phase-outs, or Reductions, including Hazard Assessment Scores

<MOEE Scores for All Candidate Substances (Bans & Phase-outs)
Primary List Substances

Hazardous Contaminants Branch
Ontario Ministry of Environment and Energy

07/12/93

| Chemical Name | CAS Number | Transport | Persistence | | | | | | BCF | Acute Toxicity | | | | | Chronic Toxicity | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | Non-Mammalian | | | Plants | | | Mammalian | | | Teratogenicity | | Carcinogenicity | | |
| | | | Summary | Air | Water | Soil | Sediment | Groundwater | Bioaccumulation | Summary | Inhalation | Dermal | Aquatic | Oral | Summary | Aquatic | Terrestrial | Summary | Aquatic | Terrestrial | Summary | Inhalation | Oral | | | | | IARC | Rank |
| aldrin | 309-00-2 | 7E | 10 | 0 | 4E | 10 | 0 | | 7 | 10 | | 4 | 10 | 6 | 10 | 10 | | 8Q | 8Q | 0 | 10 | | 10 | 8Q | | 10Q | 3 | | |
| anthracene | 120-12-7 | 10E | 7 | 0E | 0E | 7 | 4L | | 7 | 10Q | | | 10Q | | | | | | | | | | | | | | 3 | | |
| benz(a)anthracene | 56-55-3 | 10E | 10L | 0E | 0 | 10L | 10Q | | 7 | 10Q | | | 10Q | | | | | | | | | | | | | | 2A | | |
| benzo(a)pyrene | 50-32-8 | 10E | 10 | 0E | 0E | 10 | 10Q | | 7 | 10Q | | | 10Q | | | | | | | | | | | | | | 2A | | |
| benzo(ghi)perylene | 191-24-2 | 7E | 10 | 0E | 0Q | 10 | 10Q | 10E | 7L | 10Q | | | 10Q | | | | | | | | | | | | | | 3 | | |
| cadmium & compounds | 7440-43-9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 10 | 6 | | 10 | 4 | 10 | 10 | 6 | 6 | 6 | | 10 | 10E | 10 | 8 | | 10 | 2A | | |
| chlordane | 57-74-9 | 10E | 10 | 0L | 10 | 10L | 0Q | 0Q | 10 | 10 | 6L | 4 | 10 | 6 | 10 | 10 | | 8Q | 8Q | 0 | 10 | 10 | 10 | 8 | | 10 | 2B | | |
| ddt (and metabolites) | 50-29-3 | 7E | 10 | 10Q | 10E | 10 | | | 10 | 10 | | 4 | 10 | 4 | 10Q | 10Q | | 8 | 8 | 0 | 10 | | 10 | 8 | | 8 | 2B | | |
| 1,4-dichlorobenzene | 106-46-7 | 7E | 4 | 4 | 0 | 10L | 10 | 10Q | 7 | 6 | | 0 | 6 | 4 | 2 | 2 | | 6Q | 6Q | | 4 | 4 | 4 | 0 | | 10 | 2B | | |
| 3,3'-dichlorobenzidine | 91-94-1 | 7E | 10 | 0 | 0 | 10 | | 10Q | 7 | 2 | | 0L | | 2 | | | | | | | | | | | | 10 | 2B | | |
| dieldrin | 60-57-1 | 10E | 10 | | 10 | 10 | | | 10 | 10 | 8L | 6 | 10 | 8W | 10Q | 10Q | 6Q | 8Q | 8Q | 0 | 10 | | 10 | 10 | | 10 | 3 | | |
| endosulfan | 115-29-7 | 10E | 10 | 0 | 10 | 10 | | | 7 | 10 | | | 10 | 6L | 8 | 8 | | 2Q | 2Q | 2L | 8 | | 8 | 8 | | 8 | 2Q | | |
| endrin | 72-20-8 | 10E | 10 | 0L | 10 | 7L | | | 7 | 10 | | 6L | 10 | 8 | 10 | 10 | | 8 | 8 | 2 | 10 | 6 | 10 | 8Q | | 8Q | 3 | | |
| heptachlor | 76-44-8 | 10E | 10 | 4 | 0 | 10 | 4L | 0L | 10 | 10 | 6 | 4 | 10 | 6 | 6 | 6 | | 8 | 8 | 0 | 8 | | 8 | | | 10 | 2B | | |
| hexachlorobenzene | 118-74-1 | 10E | 10 | 10 | 0 | 10 | 10E | 10Q | 10 | 4Q | 2 | | 4Q | 2 | 8 | 6 | 8 | 8 | 8 | | 10 | | 10 | 6 | | 10 | 2B | | |
| alpha-hexachlorocyclohexane | 319-84-6 | 7E | 10W | 0E | 10E | 10W | | | 7 | 8 | | | 8 | | 6 | 6 | | 2 | 2 | | | | | | | 10 | 2B | | |
| gamma-hexachlorocyclohexane (lindane) | 58-89-9 | 7E | 10 | 0E | 10E | 10 | | | 7 | 10 | 4Q | 6 | 10 | 6 | 8 | 8 | | | | | 6 | 10 | 6 | 4 | | 10 | | | |
| mercury & compounds | 7439-97-6 | | 10 | 10 | 10 | 10 | 10 | 10 | 10Q | 10 | | | 10 | | | | | | | | | | | 10 | | | | | |
| mirex | 2385-85-5 | | 10Q | | 4L | 10Q | | | 10 | 8 | | 2L | 8 | 4 | 6 | 6 | 4 | 10 | 10 | 6 | 8 | 8 | | 8 | 8 | | 2B | | |
| pentachlorophenol | 87-86-5 | 7E | 10W | 7E | 0 | 10W | 10Q | 10Q | 7 | 10 | 4 | 4 | 10 | 6 | 10E | 10E | | 8 | 8 | | | | 6 | 4 | 2W | | 3 | | |
| perylene | 198-55-0 | | | | 10Q | | 10E | | 7 | 10Q | | | 10Q | | | | | | | | | | | | | | 3 | | |
| phenanthrene | 85-01-8 | 10E | 10W | 0 | 7Q | 10W | | 10Q | 7 | 10L | | | 10L | | | | | | | | | | | | | 2 | 3 | | |
| polychlorinated biphenyls (group) | 1336-36-3 | 10E | | | 10E | | | | 10 | 10 | | | 10 | | 10 | 10 | | 8Q | | | 10Q | | | 8 | | 10 | 2A | | |
| polychlorinated dibenzo-p-dioxins & dibenzofurans | n/a | | 10 | 0E | 10 | 10 | 10W | 10L | 10 | 10 | | | | 10 | 10 | 10 | 10 | 0L | | | 10 | | 10 | 10 | | 8 | 2B | | |
| toxaphene | 8001-35-2 | 7E | 10 | 10 | 10 | 10 | | | 10 | 10 | 0L | 4 | 10 | 6 | 10 | 10 | 6 | 8 | 8 | 0 | 10 | 10Q | 10 | 10Q | | 10 | 2B | | |
| tributyl tin | 688-73-3 | | 10 | | 7 | 10 | | | 7 | 10 | | | 10 | 6 | 10 | 10 | | 10 | 10 | | | | | | | | | | |
| trifluralin | 1582-09-8 | 10E | 10 | | | 10 | | | 7 | 10 | | 2 | 10 | 4 | 6 | 6 | | 10 | 4 | 10 | 8Q | | 8Q | 8Q | | 10 | | | |

<MOEE Scores for All Candidate Substances (Bans & Phase-outs)
Secondary List Substances (A Group)

Hazardous Contaminants Branch
Ontario Ministry of Environment and Energy

07/12/93

| Chemical Name | CAS Number | Transport | Persistence: Summary | Persistence: Air | Persistence: Water | Persistence: Soil | Persistence: Sediment | Persistence: Groundwater | Bioaccumulation | Acute Toxicity: Summary | Acute Toxicity: Inhalation | Acute Toxicity: Dermal | Acute Toxicity: Aquatic | Acute Toxicity: Oral | Chronic Toxicity: Non-Mammalian Summary | Chronic Toxicity: Non-Mammalian Aquatic | Chronic Toxicity: Non-Mammalian Terrestrial | Chronic Toxicity: Plants Summary | Chronic Toxicity: Plants Aquatic | Chronic Toxicity: Plants Terrestrial | Chronic Toxicity: Mammalian Summary | Chronic Toxicity: Mammalian Inhalation | Chronic Toxicity: Mammalian Oral | Teratogenic | Carcinogenic | IARC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| aldicarb | 116-06-3 | 0E | 10W | 0L | 10W | 10W | | | 4 | 10 | 4 | 8 | 10 | 10 | 8Q | 6 | 8Q | 4 | | 4 | 8 | | 8 | 10Q | 0Q | | |
| o-anisidine | 90-04-0 | | | 0E | 10E | 7L | | 10E | 0L | 2 | | | | 2 | | | | | | | | | | | 10 | 2B |
| arsenic & compounds | 7440-38-2 | | 10 | 10 | 10 | 10 | 10 | 10 | 0 | 10W | | | 10W | | | | | | | | | | | | 10 | 1 |
| asbestos | 1332-21-4 | | | | 10Q | 10Q | | | 0Q | | | | | | | | | | | | | | | | 10 | 1 |
| atrazine | 1912-24-9 | 0E | 10Q | 0E | 10Q | 10 | | | 4 | 8 | 4 | 0 | 8 | 2 | 4 | 4 | 2Q | 10 | 8 | 10 | 8 | | 8 | 2 | 2L | 2B |
| benzo(b)fluoranthene | 205-99-2 | 7E | 10L | 0E | 4E | 10L | 10Q | 10E | | | | | | | | | | | | | | | | | 10 | 2B |
| benzo(e)pyrene | 192-97-2 | | | | | | 10E | | | 10Q | | | 10Q | | | | | | | | | | | | 8L | 3 |
| benzo(j)fluoranthene | 205-82-3 | 7E | | | | | 10E | | | | | | | | | | | | | | | | | | 10 | 2B |
| benzo(k)fluoranthene | 207-08-9 | 7E | 10L | 0E | 4L | 10L | 10Q | 10E | | 10Q | | | 10Q | | | | | | | | | | | | 10 | 2B |
| beryllium (respirable & compounds) | 7440-41-7 | | 10 | 10 | 10 | 10 | 10 | 10 | 4Q | 8 | | | 8 | | | | | | | | | | | | 10 | 2A |
| carbon tetrachloride | 56-23-5 | 0E | 10 | 10 | 4E | 10E | 10E | 10E | 4 | | | | | | | | | | | | | | | | 10 | 2B |
| chloroform | 67-66-3 | 0E | 7 | 7 | 0 | 10E | | 10 | 0 | 6 | 0 | | 4 | 6 | 0 | 0 | | 0 | 0 | | 8W | 6 | 8W | 4 | 10 | 2B |
| chlorpyrifos | 2921-88-2 | 10E | 10 | 0L | 10 | 10 | | | 4 | 10 | 4 | 4 | 10 | 8 | 8Q | 6Q | 8Q | 4 | | 4 | 8 | | 8 | 6 | | |
| chromium (Cr+6 compounds) | 7440-47-3 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4Q | 8 | 6 | 4 | 8 | 6 | 4 | 4 | | 8Q | 8Q | | 10 | 10 | 6 | 8Q | 10 | 1 |
| chrysene | 218-01-9 | 10E | 10L | 0E | 7L | 10L | 10E | 10E | | 10Q | | | 10Q | | | | | | | | | | | | | 3 |
| cobalt & compounds | 7440-48-4 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4W | 10L | 4L | 4L | 10L | 4 | | | | 4L | 4L | | 10 | 8L | 10 | 6L | | |
| copper (soluble compounds) | 7440-50-8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4Q | 10 | | | 10 | 4 | 10 | 10 | | 10 | 10 | | 8 | 8 | 8Q | 2 | 2Q | |
| cyanides (group) | 57-12-5 | 0Q | | 10L | | 0L | | | 0L | 10 | 6 | 4L | 10 | 8 | | | | 4 | | 4 | 10Q | 10Q | 4Q | 6L | | |
| dibenz(a,h)acridine | 226-36-8 | 4E | | | | | 10E | | | | | | | | | | | | | | | | | | 10L | 2B |
| dibenz(a,h)anthracene | 53-70-3 | 7E | 10 | 0 | 0E | 10 | | 10Q | | | | | | | | | | | | | | | | | 10 | 2A |
| dibenz(a,j)acridine | 224-42-0 | 4E | | | | | 10E | | | | | | | | | | | | | | | | | | 10L | 2B |
| dibenzo(a,i)pyrene | 189-55-9 | 7E | 10L | 0E | 10E | 10L | | | | | | | | | | | | | | | | | | | 10 | 2B |
| 7H-dibenzo(c,g)carbazole | 194-59-2 | 10E | | | | | 10E | | | | | | | | | | | | | | | | | | 10 | 2B |
| 1,2-dichloroethane | 107-06-2 | 7E | 10W | 10W | 0 | | | | 0 | 4 | | | 2 | 4 | 0L | 0L | | | | | | | | 0L | 10 | 2B |
| 7,12-dimethylbenz(a)anthracene | 57-97-6 | 10E | 4 | 0E | 4 | 4 | | 7Q | | 10E | | | 10E | 4 | 6Q | 6Q | | 8Q | 8Q | | | | 6Q | 6 | 10 | |
| 1,8-dinitropyrene | 42397-65-9 | 4E | | | | | 10E | | | | | | | | | | | | | | | | | | 10 | 2A |
| 1,4-dioxane | 123-91-1 | 0E | 10 | 0E | 10 | 10E | | 10E | 0L | 2 | 0 | 0L | 0 | 2 | | | | 0 | 0 | | 4L | 2 | 4L | 0L | 10 | 2B |
| 1,2-diphenylhydrazine | 122-66-7 | 0E | 10E | 0 | 0 | 10E | | | 4L | 8 | | | 8 | 4L | 0L | 0L | | | | | | | | | 10 | |
| ethylene dibromide | 106-93-4 | 7E | 4E | 4E | 0 | 7Q | | | 0L | 4 | | 4 | 4 | 4 | 8Q | | 8Q | | | | 6Q | 6Q | 6Q | 2Q | 10 | 2A |
| ethylene oxide | 75-21-8 | 7E | 10W | 10W | 4W | 4W | | 4L | 0L | | | | | | | | | | | | | | | | 10 | 2A |
| bis(2-ethylhexyl)phthalate | 117-81-7 | 10E | 4 | 0E | 4 | 4E | | | 7 | 6 | 4L | 0 | 6 | 0 | 8Q | 8 | | 0Q | 0Q | | 4 | | 4 | 2 | 10 | 2B |
| fluoranthene | 206-44-0 | 10E | 10L | 0E | 10 | 10L | | 10Q | | 10Q | | | 10Q | | | | | | | | | | | | | 3 |
| hexachlorocyclopentadiene | 77-47-4 | 0E | 0 | 0E | 0 | 0 | | | 7 | 10 | 6 | 4 | 10 | 4 | 6 | 6 | | 0L | | 0L | 10 | 10 | 8 | 2 | | |
| indeno(1,2,3-cd)pyrene | 193-39-5 | 7E | 10L | 0E | 10E | 10L | | 10Q | | | | | | | | | | | | | | | | | 10 | 2B |
| lead & compounds | 7439-92-1 | | 10 | 10 | 10 | 10 | 10 | 10 | 4 | | | | | | | | | | | | | | | | 10 | 2B |
| methylene chloride | 75-09-2 | 7E | 10E | 10E | 4L | 4E | 7E | 7E | 0E | 2 | 0 | | 2 | 2 | 0L | 0L | | 0 | 0 | 0L | 4Q | 4Q | 2W | 2Q | 10 | 2B |
| nickel (respirable forms) | 7440-02-0 | | 10 | 10 | 10 | 10 | 10 | 10 | 4 | 4 | | | 4 | | | | | 8 | 8 | | 10 | 10 | 4 | 6Q | 10 | 2A |
| pyrene | 129-00-0 | 10E | 10L | 0E | 0 | 10L | | 10Q | 4 | 10Q | | | 10Q | | | | | | | | | | | | | 3 |
| silver (soluble compounds) | 7440-22-4 | | 10 | 10 | 10 | 10 | 10 | 10 | 4L | 10 | | | 10 | | | | | | | | | | | | | |
| 2,3,4,6-tetrachlorophenol | 58-90-2 | | | 10E | 4E | 10E | | | 4 | 8 | | 4 | 8 | 4 | | | | | | | | | | 2L | 10 | 2B |
| tetraethyllead | 78-00-2 | 0E | 10 | | | | | | 4 | 10 | | | 10 | | | | | 6L | 6L | | 10Q | | 10Q | 6 | | 3 |
| thiourea | 62-56-6 | 0E | 10Q | 0E | 10Q | 10L | | | 0L | 6 | | | 6 | 4 | | | | 4Q | 4Q | 0Q | 8Q | | 8Q | 2Q | 10 | 2B |
| uranium & compounds | 7440-61-1 | 10E | 10 | 10 | 10 | 10 | 10 | 10 | 4Q | 6 | | | 6 | 6 | | | | 4 | 4L | 4 | 10 | 10 | 10 | | | |
| zinc compounds | 7440-66-6 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4L | 10 | | | 10 | 4 | 4 | 4 | | 8 | 6 | 8 | 6Q | 10Q | 6Q | 0 | 8 | |

<MOEE Scores for All Candidate Substances (Bans & Phase-outs)
Secondary List Substances (B Group)

Hazardous Contaminants Branch
Ontario Ministry of Environment and Energy

07/12/93

| Chemical Name | CAS Number | Transport | Persistence | | | | | | BCF | Acute Toxicity | | | | | Chronic Toxicity | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Summary | Air | Water | Soil | Sediment | Groundwater | Bioaccumulation | Summary | Inhalation | Dermal | Aquatic | Oral | Non-Mammalian Summary | Non-Mammalian Aquatic | Non-Mammalian Terrestrial | Plants Summary | Plants Aquatic | Plants Terrestrial | Mammalian Summary | Mammalian Inhalation | Mammalian Oral | Teratogenicity | Carcinogenicity | IARC |
| aluminum (soluble compounds) | 7429-90-5 | | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 8 | | | 8 | | | | | | | | | | | 2 | | |
| chlorobenzene | 108-90-7 | 7E | 0 | 0 | 10W | 10W | 7L | 10E | 7 | 8W | | | 8W | | 2W | 2W | | | | | 4W | | 4W | | 10L | |
| hexachlorobutadiene | 87-68-3 | 0E | 10E | 10E | 10E | 10E | | | 10 | 8 | 2L | 4Q | 8 | 6 | 8 | 8 | | 0 | 0 | | 8 | 6 | 8 | 6 | 10L | 3 |
| hexachloroethane | 67-72-1 | 7E | 10 | 10 | 0 | 10L | | | 7 | 8 | | 0 | 8 | 2 | | | | 2 | 2 | | 8 | 4 | 8 | 0 | 10L | 3 |
| pentachlorobenzene | 608-93-5 | 0E | 10E | 10E | 10E | 10 | | 10E | 7 | 8 | | | 8 | | 6Q | 6Q | | | | | | | | 4 | | |
| selenium | 7782-49-2 | | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 8 | 8L | | 8 | 8 | 0 | 0 | | 6L | 6L | | 8 | | 8 | 6 | | 3 |
| 2,4,5-trichlorophenol | 95-95-4 | 7E | 0 | 0 | 0 | 10Q | 4Q | 10 | 7 | 8 | | | 8 | 2 | | | | 4L | 4L | | 4 | | 4 | 0L | 4L | 3 |
| triphenyl phosphate | 115-86-6 | 0E | 7L | | 0 | 7L | | | 10 | 8 | 2L | | 8 | 2 | 4L | 4L | | 4L | 4L | | 0L | | 0L | | | |

<MOSE Scores for All Candidate Substances (Bans & Phase-outs)
Secondary List Substances (C Group)

Hazardous Contaminants Branch
Ontario Ministry of Environment and Energy

07/12/93

| Chemical Name | CAS Number | Transport | Persistence | | | | | | BCF | Acute Toxicity | | | | | Chronic Toxicity | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Summary | Air | Water | Soil | Sediment | Groundwater | Bioaccumulation | Summary | Inhalation | Dermal | Aquatic | Oral | Non-Mammalian Summary | Non-Mammalian Aquatic | Non-Mammalian Terrestrial | Plants Summary | Plants Aquatic | Plants Terrestrial | Mammalian Summary | Mammalian Inhalation | Mammalian Oral | Teratogenicity | Carcinogenicity | IARC |
| acenaphthene | 83-32-9 | 10E | 0E | 0E | 0E | 10W | | 10E | 4 | 8 | | | 8 | | 0 | 0 | | 6 | 6 | | | | | | | |
| 4-chlorophenyl phenyl ether | 7005-72-3 | 10E | 10Q | 0E | 10Q | | | | 7 | 8 | | | 8 | | | | | | | | | | | | | |
| cyanazine | 21725-46-2 | 0E | 7W | | 4 | 7W | 4L | | 4L | 6Q | 2Q | 2 | 6Q | 4 | | | | 6 | | 6 | 8 | | 8 | 6 | 0Q | |
| 1,2-dichloropropane | 78-87-5 | 7E | 4 | 4 | 0 | 10E | | 10E | 0 | 4 | 2 | 0 | 4 | 2 | 6 | 6 | | 0L | | 0L | 8 | 8 | 8 | | 2Q | 3 |
| manganese | 7439-96-5 | | 10 | 10 | 10 | 10 | 10 | 10 | | | | | | | | | | | | | | 8 | | | | |
| palustric acid | 1945-53-5 | | | | | | | | 10L | 8L | | | 8L | | | | | | | | | | | | | |
| simazine | 122-34-9 | 0E | 10 | | 10 | 10 | | | 0 | 8 | 2 | 2 | 8 | 2 | 2 | 2 | | 10 | 10 | 8 | | | 8Q | 6Q | 10Q | |
| 1,2,3,5-tetrachlorobenzene | 634-90-2 | 7E | | | | | | | 7 | 8W | | | 8W | | | | | 4W | 4W | | 4Q | | 4Q | | | |
| 1,1,2,2-tetrachloroethane | 79-34-5 | 7E | 7E | 7E | 4L | 4L | 0L | 4L | 4L | 6 | 2 | | 6 | 4 | 0 | 0 | | 0 | 0 | | 8L | 8L | | 2L | 10Q | 3 |
| tetrachloroguaiacol | 2539-17-5 | | | | | | | | 7 | 8 | | | 8 | | | | | | | | | | | | | |
| 2,3,4,5-tetrachlorophenol | 4901-51-3 | | | | 0Q | 10L | | | 7L | 8 | | | 8 | | | | | | | | | | | | | |
| 1,2,3-trichlorobenzene | 87-61-6 | 10E | 4 | | 4 | | | | 7 | 8 | | | 8 | 2 | 8 | 8 | | 6 | 6 | | | | | 0L | | |

## Appendix 'B'

## Evaluation of Environmental Impacts/Use Impairments Associated With Substances on the Primary List of Candidate Substances for Bans, Phase-Outs or Reductions

The following contaminant-specific discussions highlight the maximum concentrations detected in water, sediment and biological organisms from various locations in the Great Lakes Basin. It must be emphasized, however, that concentrations in each area can span a wide range, from 'non-detected' to levels exceeding criteria.

### Aldrin

Aldrin is rapidly converted to dieldrin (and other compounds) both photochemically and by aquatic organisms, however dieldrin is very persistent and lipophilic, resulting in food chain bioaccumulation (Cox & Ralston, 1990). Aldrin is still occasionally detected in the aquatic environment, and in some areas its levels exceed criteria for water and/or sediment (Tables 2.4 and 2.5).

Aldrin was not found in any open lake water samples from Lakes Superior, Huron, Erie and Ontario and from Georgian Bay at a detection limit of 0.007 to 0.011 ng/l (IJC, 1989). However, concentrations in a few samples from the Great Lakes Basin or nearshore areas have exceeded the PWQO of 1 ng/l for the protection of aquatic life (Table 2.5). For example, in the Toronto area, maxima include 4 ng/l at the mouth of the Don River (Boyd, 1988) and 3 ng/l and 2 ng/l in Ashbridges Bay and at the East Headland (Jaagumagi & Persaud, 1992), respectively. Monitoring data for 48 Ontario tributaries show that aldrin was present in only 0.4% of water samples collected during the period 1979 to 1982. About 0.2% of the samples contained levels above the PWQO (OMOE, unpublished data).

Surficial sediments contained up to 0.003 mg/kg (dry weight) of aldrin in Thunder Bay (Boyd, 1990), 0.017 mg/kg in Black Ash Creek, tributary to Collingwood Harbour (Beak, 1988a) and 0.033 mg/kg near Cornwall in the St. Lawrence River (OMOE & EC, 1990). The above values exceed the 'lowest effect level' sediment quality guideline of 0.002 mg/kg. Such exceedences therefore result in concerns over the toxicity of this pesticide to the more sensitive species of sediment-dwelling organisms and possible biomagnification up through the food chain. Also, open water disposal of contaminated dredgates would be restricted.

Benthic invertebrates contained up to: 0.008 mg/kg, 0.006 mg/kg, 0.032 mg/kg and 0.005 mg/kg (wet weight) in Toronto's Humber Bay, Inner Harbour, East Headland and Bluffers Park areas, respectively (Jaagumagi & Persaud, 1992). Burrowing mayfly larvae and juvenile fathead minnows exposed to Canagagigue Creek sediments contained up to 0.039 mg/kg and 0.060 mg/kg, respectively (Jaagumagi et al., 1991a), and burrowing mayfly larvae exposed to Rice Lake sediments contained up to 0.005 mg/kg (Jaagumagi & Petro, 1992). Emergent (adult) mayflies from inland waters contained up to 0.0003 mg/kg (dry weight) (Kovats & Ciborowski, 1989).

Longnose dace (minnows) from the Grand River contained 0.005 mg/kg, wet weight (Jaagumagi et al., 1991b).

Aldrin is routinely analyzed for in young-of-the-year fish and sport fish samples from Ontario waters; however, it has not been detected in recent forage fish samples (Suns et al., 1991). Although there is no Canadian guideline for the protection of human consumers of fish, aldrin is only present at low concentrations (below the GLWQA objective of 0.3 mg/kg) or is not detected (Cox & Ralston, 1990).

Anthracene

As with the other PAH compounds considered in this section, anthracene is a by-product of the combustion of fossil fuels, such as: forest fires; heat and power generation; and internal combustion engines. Major industrial sources include coal tar processing, petroleum refining, shale refining, coal, coke and kerosene processing. Many of these compounds are also present in asphalt or bitumen (deBarros, 1984; Verschueren, 1983).

There are presently no criteria for this PAH compound regarding allowable or safe concentrations in receiving waters, sediment or aquatic biota. However, the GLWQA states that: "For other contaminants for which Specific Objectives have not been defined, but which can be demonstrated to be persistent and are likely to be toxic, the concentration of such compounds in water or aquatic organisms should be substantially absent, i.e., less than detection levels as determined by the best scientific methodology available" (IJC, 1987). Monitoring has detected elevated concentrations (i.e., above background or control) of anthracene in samples collected near or downstream of Ontario discharges and previous coal gasification sites, particularly in industrialized urban areas. Consequently, there are impairments in a number of Great Lakes Areas of Concern. Furthermore, sediments in some areas exceed the OMOE sediment quality guideline for 'total PAHs' (Tables 2.4 and 2.5). For example, along the Ontario shore of the St. Marys River, whole water samples contained up to 173 ng/l in 1986 (UGLCCS, 1988). Levels of anthracene in the Detroit River downstream of Turkey Creek were 2 ng/l in 1987 (Cowell, 1990).

Anthracene is also adsorbed to fine particulate material. For example, up to 2.44 mg/kg (on a dry weight basis) of anthracene were associated with the suspended sediment (particulate) phase of St. Marys River water (UGLCCS, 1988).

Concentrations in surficial (recent) sediments were up to 4.32 mg/kg (dry weight basis) in Thunder Bay Harbour (EC, 1988), 6.07 mg/kg in the St. Marys River (Kauss, 1991), 2.84 mg/kg in the St. Clair River (OMOE, unpublished 1990 data), 5.50 mg/kg in Ashbridges Bay, Toronto (Jaagumagi et al., 1991d), 6.20 mg/kg in the Bay of Quinte (Poulton, 1990), and 4.02 mg/kg in the St. Lawrence River (Jaagumagi and Persaud, 1992). Concentrations up to 88.1 mg/kg were found in an area of Hamilton Harbour contaminated with coal tar (Murphy et al., 1990). All of these maxima exceed the OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs'. This causes concern over anthracene toxicity to the more sensitive species of sediment-dwelling organisms and its possible biomagnification in the food

chain (Persaud et al., 1991). Also, open water disposal of dredged sediments would be restricted.

Fewer data are available on anthracene concentrations in biota. This PAH has not been detected in young-of-the-year fish samples from a number of Great Lakes sampling sites (Suns et al., 1991), or in adult sport fish from the St. Marys River and the lower Niagara River (OMOE, unpublished 1989 data). Nevertheless, it was accumulated to detectable levels by benthic invertebrates such as freshwater mussels. In 1985, after three weeks of exposure in the St. Marys River in cages, mussels at Ontario stations contained up to 0.123 mg/kg on a wet weight basis (Kauss and Hamdy, 1991). After 18 weeks in the St. Clair and Detroit Rivers, mussels contained up to 0.028 mg/kg and 0.011 mg/kg, respectively (OMOE, unpublished 1984 data).

Benzo[a]pyrene

Concentrations of benzo[a]pyrene exceeded criteria for sediments (Table 2.4) in a number of Ontario Great Lakes Areas of Concern, particularly in industrialized urban areas (Table 2.5).

In the St. Marys River, whole water samples contained up to 140 ng/l (estimated) (UGLCCS, 1988), which is above the recommended IJC objective of 10 ng/l for the protection of aquatic life. In Turkey Creek, a tributary of the Detroit River, the concentration in water was 10 ng/l (Cowell, 1990). The mean 'recombined whole water' benzo[a]pyrene concentration at Niagara-on-the-Lake was 1.59 ng/l during the period 1986-1987 (Niagara River Data Interpretation Group, 1988).

Up to 3.88 mg/kg (dry weight) were associated with the suspended sediment phase of water in the St. Marys River (UGLCCS, 1988). In the Niagara River, the 0.993 kg/d increase in the suspended sediment-associated daily loading between Fort Erie and Niagara-on-the-Lake was significant (Niagara River Data Interpretation Group, 1988).

Concentrations of benzo[a]pyrene in surficial sediments ranged up to 5.79 mg/kg (dry weight) in the St. Marys River (Kauss, 1992), 2.99 mg/kg in the St. Clair River (OMOE, unpublished 1990 data), 1.73 mg/kg in the Grand River at Kitchener-Waterloo (Jaagumagi et al., 1991b), 40.2 mg/kg in Kettle Creek which discharges to eastern Lake Erie (Griffiths, 1988), 69.2 mg/kg in Hamilton Harbour (Murphy et al., 1990), 4.30 mg/kg in Toronto's Ashbridges Bay (Jaagumagi et al., 1991d), 2.47 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992), 1.70 mg/kg in the Bay of Quinte (Poulton, 1990) and 5.68 mg/kg in the St. Lawrence River (Jaagumagi and Persaud, 1992). Many of these maxima exceed the OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs', and therefore there is concern over toxicity of this compound to the more sensitive species of sediment-dwelling organisms and its possible biomagnification in the food chain (Persaud et al., 1991). Also, open water disposal of contaminated dredgate would be restricted.

Benzo[a]pyrene is accumulated by some aquatic invertebrate species. For example, maximum concentrations in caged mussels were 0.013 mg/kg (wet weight) in caged mussels exposed in the St. Marys River (Kauss and Hamdy, 1991), 0.020 mg/kg in the St. Clair River, 0.027 mg/kg in the Detroit River (OMOE, unpublished 1984 data) and 0.039 mg/kg in Chippawa Creek, a tributary of the Niagara River (Anderson et al., 1991). These levels are below the recommended IJC objective of 1.000 mg/kg for the protection of higher trophic levels. In contrast, burrowing mayfly larvae and fathead minnows exposed to contaminated Hamilton Harbour sediments under laboratory conditions accumulated up to 1.572 mg/kg and 0.209 mg/kg, respectively (Krantzberg, 1991), the former being above the IJC objective. This PAH has not been detected in young-of-the-year fish samples from the Great Lakes (Suns et al., 1991), or in adult sport fish from the St. Marys River and the lower Niagara River (OMOE, unpublished 1989 data).

Benzo[g,h,i]perylene

Concentrations of benzo[g,h,i]perylene exceed the OMOE sediment criterion for 'total PAHs'. Although there are presently no numerical criteria for safe concentrations of this compound in ambient water or aquatic biota, elevated concentrations have been detected in samples collected near or downstream of Ontario discharges in industrialized urban areas. The GLWQA states that such contaminants should not be detectable in water or aquatic organisms (IJC, 1987).

In the St. Marys River, whole water samples contained up to 29 ng/l of this PAH and up to 0.822 mg/kg (dry weight) was associated with the suspended sediment phase (UGLCCS, 1988).

Concentrations of this compound in surficial sediments ranged up to 1.76 mg/kg (dry weight) in Thunder Bay Harbour (EC, 1988), 3.85 mg/kg in the St. Marys River (Kauss, 1992), 1.15 mg/kg in the St. Clair River (OMOE, unpublished 1990 data), 60.6 mg/kg in Hamilton Harbour (Murphy et al., 1990) and 1.62 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992). Some of these values exceed the OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs'. Consequently, there is concern over benzo[g,h,i]perylene toxicity to the more sensitive species of sediment-dwelling organisms and its possible biomagnification in the food chain (Persaud et al., 1991). Also, open water disposal of dredged sediment would be restricted.

Low concentrations of benzo[g,h,i]perylene have been found in some aquatic species. Maximum concentrations were 0.001 mg/kg (wet weight) in caged mussels exposed in the St. Marys River (Kauss and Hamdy, 1991) and 0.003 mg/kg in the St. Clair River (OMOE, unpublished 1984 data). In contrast, burrowing mayfly larvae and fathead minnows exposed to contaminated Hamilton Harbour sediments accumulated up to 0.350 mg/kg and 0.062 mg/kg, respectively (Krantzberg, 1991). This PAH has not been detected in young-of-the-year fish samples from a number of Great Lakes sampling sites (Suns et al., 1991), or in adult sport fish from the St. Marys River and the lower Niagara River (OMOE, unpublished 1989 data).

Benz[a]anthracene

Concentrations of benz[a]anthracene in some sediments exceed the OMOE sediment criterion for 'total PAHs'. Elevated levels of this PAH compound have been found in water samples collected near or downstream of Ontario discharges, particularly in urban areas. At present, there are no criteria for safe concentrations of this aromatic compound in ambient water or aquatic biota. However, the GLWQA states that such contaminants should not be detectable in water or aquatic organisms (IJC, 1987).

In the St. Marys River, whole water samples contained up to 286 ng/l (UGLCCS, 1988). In the Niagara River, the mean 'recombined whole water' benz[a]anthracene concentration at Niagara-on-the-Lake was 2.58 ng/l (Niagara River Data Interpretation Group, 1988).

High concentrations of benz[a]anthracene can be associated with the suspended sediment phase of water. In the St. Marys River, up to 7.684 mg/kg (dry weight) were detected in this phase (UGLCCS, 1988).

Concentrations of this PAH in surficial sediments ranged up to 3.68 mg/kg (dry weight) in Thunder Bay Harbour (E C, 1988), 9.74 mg/kg in the St. Marys River (Kauss, 1992), 4.93 mg/kg in the St. Clair River (OMOE, unpublished 1990 data), 102.0 mg/kg in Hamilton Harbour (Murphy et al., 1990), 4.90 mg/kg in Toronto's Ashbridges Bay (Jaagumagi and Persaud, 1992), 2.90 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992), 3.20 mg/kg in the Bay of Quinte (Poulton, 1990) and 10.10 mg/kg in the St. Lawrence River (Jaagumagi and Persaud, 1992). These maxima are all above the OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs', and therefore there is concern over benz[a]anthracene toxicity to the more sensitive species of sediment-dwelling organisms and its possible biomagnification in the food chain (Persaud et al., 1991). Also, open water disposal of dredged sediment would be restricted.

Elevated (above background or control) concentrations of benz[a]anthracene have been detected in some aquatic invertebrates. For example, freshwater mussels exposed in Chippawa Creek, an Ontario tributary to the Niagara River, contained 0.036 mg/kg (wet weight) after three weeks (Anderson et al., 1991). Burrowing mayfly larvae and fathead minnows exposed to sediments from Wheatly Harbour and from Muddy Creek (a tributary of Wheatly Harbour) accumulated up to 0.097 mg/kg and 0.385 mg/kg, respectively (OMOE, EC, OMNR and OMAF, 1991). Burrowing mayfly larvae and fathead minnows exposed to contaminated Hamilton Harbour sediments accumulated up to 4.310 mg/kg and 0.400 mg/kg, respectively (Krantzberg, 1991). Although this PAH has not been detected in young-of-the-year fish samples from the Great Lakes (Suns et al., 1991), it has been detected at concentrations close to the detection level of 0.005 mg/kg in some samples of adult sport fish. In the St. Marys River, the maximum benz[a]anthracene concentrations in walleye, chinook salmon and pink salmon were 0.010 mg/kg, 0.008 mg/kg and 'not detected', respectively; it was not detected in fish from the lower Niagara River (OMOE, unpublished 1989 data).

Cadmium

Concentrations of cadmium in water and sediment frequently exceed Ontario water and sediment quality objectives (Tables 2.4 and 2.5) in a number of areas in the Great Lakes Basin and elsewhere in Ontario. No available criterion exists for safe levels of cadmium in biota.

When detected in surface waters during routine analysis, cadmium levels equal or exceed the PWQO or IJC Agreement objective of 0.2 µg/L, as the routine Ministry detection limit is equal to this value. Nevertheless, nonroutine low-level methods allowed the detection of this metal at very low levels in open waters of the Great Lakes. For example, Rossmann and Barres (1988) found median levels of dissolved cadmium ranging from 0.006 µg/L in Lake Superior to 0.067 µg/L in Lake Erie, and of total cadmium ranging from 0.027 µg/L in Lake Superior to 0.096 µg/L in Lake Ontario. Other maxima found in Areas of Concern include: 40 µg/L in Jackfish Bay (OMOE, EC, OMNR and DFO, 1991), 15 µg/L in Peninsula Harbour (OMOE, EC, OMNR and F&OC, 1991b), 7 µg/L in Spanish Harbour (OMOE, OMNR, F&OC, and NWRI), and 5 µg/L in Thunder Bay (OMOE, EC, OMNR and DFO, 1991), 1.7 µg/L in Hamilton Harbour (Poulton, 1986), 1.46 µg/L in Toronto Waterfront near the Main STP (Poulton and Beak Consultants, 1991), 1.0 µg/L in Nipigon Bay (MOE, EC, MNR, and F&OC, 1991a), and 0.77 µg/L in the Trenton Channel of the Detroit River (MDNR and MOE, 1991). While the maximum in the St. Clair River at the Walpole I. WTP intake was found to be 0.15 µg/L (MOE and MDNR, 1991), 14 to 75% of samples collected in a series of St. Clair R. - L. St. Clair tributaries exceeded the PWQO (Johnson and Kauss, 1991) with a maximum of 2.0 µg/L at Cole Drain. Several other Areas of Concern also report minor PWQO exceedences (maxima < 2 µg/L). A maximum value of 10 µg/L at Niagara on the Lake was also reported for 1978-81 by Allan (1986); however, more recent data (Niagara River data interpretation group, 1990) indicated that the maximum levels in 1988-89 had decreased to 0.18 and 0.17 µg/L at Fort Erie and Niagara on the Lake, respectively (90% confidence level maxima), i.e. just below the PWQO. Inland, maximum values have been reported of 3 µg/L in the Don River (Bodo, 1989), 3.2 µg/L in the Rainy River downstream of the Boise-Cascade mill (Beak, 1990), 1.6 µg/L in Moose Creek (Jorgensen, 1991), and 1.5 µg/L in the Porcupine River near Timmins (Carbone, 1987). Data from the Ministry's Provincial Water Quality Monitoring Network (MOE, unpublished data) indicate that on a province-wide basis, 20 % of samples collected between 1979 and 1992 exceeded the PWQO. Most of these were in the Canadian Shield areas, with 44% exceedence in the Lake Superior area and 41% exceedence in the Rainy River area. Levels of exceedence were lower in other parts of Ontario.

Concentrations of cadmium associated with suspended matter have been found as high as 19.0 mg/kg in 1987 in the Toronto Waterfront near the Humber Bay STP (Boyd, 1992). In the St. Clair-Detroit R. system, maximum concentrations of 11.0 mg/kg were found for both the Cole Drain and Detroit River (Johnson and Kauss, 1991). Other maxima of interest include 10.8 mg/kg in Hamilton Harbour (Mayer and Manning, 1989), 6.2 mg/kg in the Don River (Bodo, 1989), and 4.7 mg/kg in Thunder Bay (OMOE, EC, OMNR and DFO, 1991). Some "typical" values quoted elsewhere (Allan, 1986) include 6.6 mg/kg at Lake Erie and 8.2 mg/kg in the upper Niagara River.

Widespread exceedences of the Provincial Sediment Quality Guidelines for cadmium are evident. Maximum values in some of the Areas of Concern exceed the Severe Effect Level (SEL) value of 10 mg/kg, as follows: 41 mg/kg in the Detroit River (MDNR and OMOE, 1991); 20.5 mg/kg in Hamilton Harbour near the Burlington STP (Mayer and Manning, 1989); 19.7 mg/kg in the Niagara River (Allan et al., 1981); 15.3 mg/kg in a separate Hamilton Harbour study (Krantzberg, 1991). A maximum value of 13.7 mg/kg for Lake Erie has also been reported (Allan et al., 1981). Krantzberg and Stokes (1990) has also reported a maximum of 16 mg/kg at Plastic Lake. The In-Place Pollutants studies summary for 1983-87 has found maximum sediment bulk cadmium levels of 83 mg/kg in the Detroit River, 58 mg/kg in Frenchman's Bay, 31 mg/kg in the Toronto Harbour East Headland, and 26 mg/kg at Humber Bay (Jaagumagi and Persaud, 1991). The proportion of Hamilton Harbour sediments exceeding the SEL was measured at 64% (EC and MOE, 1991). A review (Mudroch et al., 1988) of surficial sediment cadmium levels found maxima exceeding the SEL at 22 and 20.6 mg/kg in Lake Ontario embayments and nondepositional zones, respectively, and 13.7 mg/kg in Lake Erie depositional basins. Thus it is seen that severe contamination of Ontario sediments by cadmium is quite widespread, based on the SEL, above which pronounced disturbance of the sediment-dwelling community can be expected and restrictions on dredging activities (i.e., open water disposal of dredged materials) would be imposed (Persaud et al., 1991). Some other notable maxima in Areas of Concern include 4.7 mg/kg at Thunder Bay (OMOE, EC, OMNR and DFO, 1991), 4 mg/kg in the Bay of Quinte at Belleville (OMOE, EC, F&OC, OMNR and OMAF, 1990), 3.2 mg/kg at St. Mary's River (Kauss, 1991), 1.6 µg/g at Nipigon Bay in 1988 (MOE, EC, MNR, and F&OC, 1991a), 2.1 µg/g at Jackfish Bay (MOE, EC, MNR, DFO, 1991), and 2.30 mg/kg at Cornwall (Richman, 1991). "Typical" values of 2.5 mg/kg have been reported for Lakes Erie and Ontario (Allan, 1986). In addition, a maximum of 8 mg/kg has been recorded for Plastic Lake (Young and Harvey, 1991). Many additional places exhibit exceedences of the LEL value of 0.6 mg/kg. Based on the latter guideline, there is concern regarding cadmium toxicity to the more sensitive species of sediment-dwelling organisms and possible bioaccumulation through the food chain (Persaud et al., 1991).

A maximum recorded value of 35.7 mg/kg in "net plankton" found in McFarlane Lake near Sudbury (Yan et al., 1989b) was almost five times higher than that (8 mg/kg) in Plastic Lake (Yan et al., 1989a), and more than an order of magnitude greater than the largest value found in the Great Lakes (2.7 mg/kg at Whitefish Bay, Lake Superior; Allan et al. (1981). In clams (Lampsilis radiata), maximum cadmium levels of 19.0 mg/kg in Lake St. Clair, 14.7 mg/kg in St. Clair River, and 6.2 mg/kg in Detroit River were found by Pugsley et al., (1988). With regard to benthic animals, chironomids were found to exhibit an average level of 6 mg/kg (dry) in six south central Canadian Shield lakes (Young and Harvey, 1991). Elsewhere, chironomids were found to have maximum values of 2.1 mg/kg (dry) at Plastic Lake (Krantzberg and Stokes, 1990), 1.22 mg/kg (wet) in the Bay of Quinte (DFO Burlington cited by Poulton, 1990), 0.09 mg/kg (wet) at Collingwood (OMOE and EC, 1989) and 0.08 mg/kg (wet) at Penetang in Severn Sound (OMOE, EC, OMNR and OMAF, 1988). Amphipods were found to have a maximum cadmium level of 0.24 mg/kg (wet) at Collingwood (OMOE and EC, 1989), and Pontoporeia had a maximum cadmium level of 4.9 mg/kg (dry) at Whitefish Bay in Lake Superior (Allan et al., 1981).

Sculpin from Collingwood Harbour contained up to 0.42 mg/kg of cadmium (OMOE and EC, 1989), whereas the maximum found in the Bay of Quinte was 0.09 mg/kg (DFO, cited by Poulton, 1990). Walleye were found to have a maximum level of 0.092 mg/kg in the St. Clair River (OMOE and MDNR, 1991), while they had undetectable cadmium levels (<0.02 mg/kg) in the Bay of Quinte. In the lower Niagara River, lake trout, rainbow trout, coho salmon, and brown trout had maximum cadmium levels of .044, .040, .040, and .039 mg/kg respectively (OMOE, EC, OMNR and F&OC, 1991). A comprehensive 1983 study of adult herring gulls found kidney levels of 2.16 mg/kg (Hamilton Harbour), 1.75 mg/kg (Middle Island, Lake Erie), 1.33 mg/kg (Double Island, North Channel), and 1.53 mg/kg (Agawa Rock, Lake Superior) (Struger et al., 1987). The same study found cadmium levels in herring gull livers about five times lower than the above, indicating organ-specific bioaccumulation.

## Chlordane

Although commercial chlordane is principally composed of alpha-chlordane, technical grade chlordane contains two major components, alpha(cis) and gamma(trans)chlordane, as well as related chlorinated compounds, including two isomers of heptachlor (deBarros, 1984; Verschueren, 1983). This organochlorine insecticide was mainly used for the domestic control of termites and carpenter ants and for the control of agricultural soil pests such as the corn rootworm and the strawberry root weevil. The high persistence and high lipid solubility of chlordane resulted in concerns about its bioaccumulation in the aquatic food chain. As a result, agricultural uses were restricted in the late 1970's. In 1985, domestic sales were also curtailed, although it was still permitted for termite control (Cox & Ralston, 1990). With the subsequent cessation of production in the United States new supplies of chlordane are no longer available in Ontario. Chlordane is still detectable in the aquatic environment in some areas; however its levels exceed only the criterion for sediment (Tables 2.4 and 2.5).

Mean water concentrations of alpha-chlordane in the Great Lakes were 0.027 ng/l in Lake Superior, 0.039 ng/l in Lake Huron, 0.047 ng/l in Georgian Bay, 0.056 ng/l in Lake Erie, and 0.033 ng/l in Lake Ontario; gamma-chlordane was only found in Lake Superior, and Lake Erie, with mean concentrations of 0.011 ng/l and 0.038 ng/l, respectively (IJC, 1989). These levels, as well as those in Areas of Concern or in the Great Lakes Basin are well below the PWQO of 60 ng/l (total chlordane) for the protection of aquatic life. For example, monitoring data from 48 Ontario tributaries for the period 1979 to 1982 indicate that chlordane was present in only 0.9% of water samples; however, none of the concentrations were above the PWQO (OMOE, unpublished data). In contrast, levels of up to 80 ng/l gamma-chlordane have been detected in the effluents of municipal sewage treatment plants discharging to the Bay of Quinte area (Poulton, 1990).

Concentrations of chlordane compounds on suspended sediment ranged as high as 0.002 mg/kg (dry weight) gamma-chlordane and 0.078 mg/kg oxychlordane in Thunder Bay (Boyd, 1990). All of the loadings of chlordane from tributaries discharging to the St. Clair River, Lake St. Clair and the Detroit River were associated

with the suspended sediment phase. The maximum concentrations of alpha-chlordane, 0.020 mg/kg, and of gamma-chlordane, 0.030 mg/kg, were found in Turkey Creek, a Detroit River tributary (Johnson & Kauss, 1991). In the Toronto area, the maximum concentrations of 0.033 mg/kg, 0.035 mg/kg and 0.010 mg/kg (dry weight) of alpha- and gamma-chlordane and oxychlordane, respectively, were all found at the mouth of Mimico Creek (Boyd, 1988).

Surficial sediments contain up to the following concentrations of chlordane compounds: 0.013 mg/kg oxychlordane in the Kaministikwia River at Thunder Bay (Jaagumagi & Persaud, 1992); 0.005 mg/kg oxychlordane in Peninsula Harbour (Jardine & Simpson, 1990); 0.010 mg/kg gamma-chlordane and 0.015 mg/kg oxychlordane in the St. Marys River (Jaagumagi & Persaud, 1992); 0.003 mg/kg alpha-chlordane, 0.009 mg/kg gamma-chlordane and 0.025 mg/kg oxychlordane in tributaries to Collingwood Harbour (Beak, 1988a); 1992); 0.055 mg/kg total chlordanes in the Detroit River (Thornley & Hamdy, 1984); 0.005 mg/kg alpha- and 0.002 mg/kg gamma-chlordane in Lake Erie's Inner Long Point Bay (Ross & Hamdy, 1983); 0.002 mg/kg of the gamma isomer in Canagagigue Creek (Jaagumagi et al., 1991a); 0.003 mg/kg alpha-chlordane in the Niagara River (Creese, 1987); 0.045 mg/kg alpha-chlordane and 0.030 mg/kg gamma-chlordane in Hamilton Harbour (Jaagumagi & Persaud, 1992); 0.072 mg/kg alpha-chlordane and 0.100 mg/kg gamma-chlordane in the Sam Smith lakefilling area in Toronto (Poulton, 1992); 0.010 mg/kg each of alpha-chlordane, gamma-chlordane and oxychlordane in Humber Bay (Jaagumagi & Persaud, 1992); 0.010 mg/kg alpha-chlordane and 0.013 mg/kg gamma-chlordane in Toronto Harbour (Jaagumagi & Persaud, 1992); 0.104 mg/kg alpha-chlordane, 0.100 mg/kg gamma-chlordane and 0.036 mg/kg oxychlordane in Toronto's Ashbridges Bay (Jaagumagi & Persaud, 1992); 0.003 mg/kg gamma-chlordane and 0.002 mg/kg oxychlordane, respectively, near Maitland (Wilkins, 1988) and 0.012 mg/kg each of alpha- and gamma-chlordane near Cornwall (OMOE & EC, 1990). The sums of chlordane isomers at many of the above locations exceed the 'lowest effect level' sediment quality guidelines of 0.007 mg/kg for total chlordane. Consequently, these exceedences lead to concerns over the open water disposal of dredged sediments and the toxicity of chlordane compounds to the more sensitive species of sediment-dwelling organisms and possible biomagnification up through the food chain.

Net plankton from a variety of southern Ontario lakes contained from 0.0003 to 0.025 mg/kg (dry weight) of alpha-chlordane and from not detected to 0.012 mg/kg gamma-chlordane (Taylor et al., 1990).

The maximum wet weight concentrations of chlordanes in samples of benthic macroinvertebrates from the following areas were: 0.017 mg/kg alpha-chlordane and 0.007 mg/kg oxychlordane in invertebrates from the Kaministikwia River in Thunder Bay (Jaagumagi & Persaud, 1992); 0.004 mg/kg each of the alpha and gamma isomers in oligochaetes from the St. Marys River (Jaagumagi et al., 1991c); 0.010 mg/kg in oligochaetes from Collingwood Harbour (OMOE & EC, 1989); 0.008 mg/kg alpha-chlordane and 0.010 mg/kg gamma-chlordane and 0.005 mg/kg alpha-chlordane and 0.006 mg/kg gamma-chlordane in invertebrates from Humber Bay and Ashbridges Bay, respectively (Jaagumagi & Persaud, 1992). Caged mussels accumulated maximum mean concentrations of 0.002 mg/kg of the alpha and gamma isomers

during their exposure in the St. Clair and Detroit Rivers, respectively (Kauss & Hamdy, 1985) and 0.002 mg/kg of gamma-chlordane in the Welland River (Anderson et al., 1991).

Levels of chlordane in fish ranged as high as: 0.008 mg/kg and 0.005 mg/kg of the alpha and gamma isomers in sculpin from the St. Marys River (Jaagumagi et al., 1991c); 0.012 mg/kg alpha-chlordane in sculpin from Collingwood Harbour (OMOE & EC, 1989); 0.004 mg/kg of each isomer in juvenile fathead minnows after exposure to Canagagigue Creek sediment (Jaagumagi et al., 1991a); and 0.03 mg/kg total chlordane in sculpin from the Bay of Quinte (Poulton, 1990).

Total chlordane concentrations in young-of-the-year spottail shiners from the Great Lakes and the St. Lawrence River declined significantly between the mid 1970's and the most recent (1986-1988) samples from some locations in Lakes Erie and Ontario. Levels in all recent samples from Ontario Great Lakes waters are well below the New York State criterion of 0.500 mg/kg (Newell et al., 1987). For example, the highest mean concentration in these fish during the period 1986-1988 was 0.019 mg/kg at the mouth of Mimico Creek in Lake Ontario (Suns et al., 1991).

No Canadian guideline has been established for the protection of human consumers of fish; however, the United States Food and Drug Administration has a consumption guideline of 0.3 mg/kg. Although chlordanes are still being detected in the edible portions of Ontario sport fish, recent levels in fish from a number of locations are at such low levels that they would not affect the consumption of the fish (Cox & Ralston, 1990).

DDT and Metabolites

The use of DDT was restricted in Ontario in 1969 to the control of rodents and bats in enclosed areas by special permit. In the United States, its use was banned in 1972. However, the pesticide dicofol (Kelthane) has been found to be contaminated with from 2.5% to about 6% of DDT residues. The latter include the o,p and p,p' isomers of DDT, as well as DDD, DDE and extra chlorine DDT (Kauss and Post, 1987).

Lakewide mean water concentrations of p,p'-DDE increase from Lake Superior to Lake Ontario: 'not detected' in Lake Superior, 0.012 ng/l in Lake Huron, 0.020 ng/l in Georgian Bay, 0.032 ng/l in Lake Erie, and 0.050 ng/l in Lake Ontario (IJC, 1989). These average levels are well below the PWQO for DDT plus metabolites of 3 ng/l for the protection of aquatic life. Nevertheless, the maximum concentrations in some Areas of Concern or in the Great Lakes watershed exceeded the PWQO (Table 2.5). These include 19 ng/l p,p'-DDE in Thunder Bay (Boyd, 1990), 4 ng/l p,p'-DDE at the mouth of Pike Creek, a tributary of Lake St. Clair (Johnson and Kauss, 1991), 17 ng/l p,p'-DDT in Canagagigue Creek, a tributary of the Grand River which discharges to Lake Erie (Jaagumagi et al., 1991a) and 5 ng/l of p,p'-DDT at a lakefilling area in the Toronto waterfront (Boyd, 1988).

In tributaries discharging to the St. Clair River, Lake St. Clair and the Detroit River, virtually all of the loadings of DDT and its metabolites were associated with the

suspended sediment phase. The maximum concentrations on a dry weight basis of o,p-DDT (0.015 mg/kg), p,p'-DDT (0.045 mg/kg), p,p'-DDD (0.050 mg/kg) and of p,p'-DDE (0.033 mg/kg) were found in Turkey Creek, a Detroit River tributary (Johnson and Kauss, 1991). In the Toronto area, the maximum concentrations of 0.010 mg/kg o,p-DDT and 0.060 mg/kg p,p'-DDT were associated with a lakefilling area on the waterfront, whereas the maximum of 0.025 mg/kg p,p'-DDD was found at the mouths of Mimico Creek, the Don River and the Humber River, all Lake Ontario tributaries. A maximum of 0.088 mg/kg p,p'-DDE was recorded in the Don River (Boyd, 1988).

Surficial sediments contain up to: 0.002 mg/kg (dry weight) each of o,p-DDT and p,p'-DDD and 0.004 mg/kg of p,p'-DDE in Thunder Bay (Boyd, 1991); 0.005 mg/kg p,p'-DDE in Peninsula Harbour (Jardine and Simpson, 1990); 0.037 mg/kg p,p'-DDD and 0.088 mg/kg p,p'-DDE in the St. Marys River (Jaagumagi et al., 1991c); 0.010 mg/kg p,p'-DDT, 0.015 mg/kg p,p'-DDD and 0.036 mg/kg p,p'-DDE in Collingwood Harbour (Jaagumagi and Persaud, 1992); 0.008 mg/kg p,p'-DDE in Midland Bay (Jaagumagi and Persaud, 1992); 0.010 mg/kg p,p'-DDE in Penetang Harbour (Jaagumagi and Persaud, 1992); 0.025 mg/kg p,p'-DDT, 0.050 mg/kg p,p'-DDT and 0.049 mg/kg p,p'-DDE in the St. Clair River (OMOE and MDNR, 1991); 0.049 mg/kg total DDT in the Detroit River (Thornley and Hamdy, 1984); 0.015 mg/kg p,p'-DDD and 0.047 mg/kg p,p'-DDE mg/kg in Wheatly Harbour (OMOE, EC, OMNR and OMAF, 1991); 0.030 mg/kg o,p-DDT, 6.030 mg/kg p,p'-DDT, 0.150 mg/kg p,p'-DDD and 0.050 mg/kg p,p'-DDE in Canagagigue Creek (Jaagumagi et al., 1991a); 0.030 mg/kg p,p'-DDT in the Grand River (Jaagumagi et al., 1991b); 0.017 mg/kg p,p'-DDE in the Niagara River (Creese, 1987); 0.022 mg/kg p,p'-DDE in Port Weller Harbour (Jaagumagi and Persaud, 1992); 0.005 mg/kg o,p-DDT, 0.077 mg/kg p,p'-DDT, 0.050 mg/kg p,p'-DDD and 0.096 mg/kg p,p'-DDE in Hamilton Harbour (OMOE, OMNR, OMAF, EC, FOC and RBG, 1989; Jaagumagi and Persaud, 1992); 0.030 mg/kg p,p'-DDT, 0.215 mg/kg p,p'-DDD and 0.034 mg/kg p,p'-DDE in Toronto's Inner Harbour (Jaagumagi and Persaud, 1992); 0.010 mg/kg p,p'-DDD and 0.024 mg/kg p,p'-DDE in Rice Lake (Jaagumagi and Persaud, 1992); 0.100 mg/kg p,p'-DDT and 0.034 mg/kg p,p'-DDE in the Bay of Quinte (Poulton, 1990; Jaagumagi and Persaud, 1992); and 0.015 mg/kg and 0.006 mg/kg, respectively, of p,p'-DDE near Maitland and Cornwall in the St. Lawrence River (Wilkins, 1988; OMOE and EC, 1990). These values exceed the 'lowest effect level' sediment quality guidelines of 0.007 mg/kg for total DDT, 0.008 mg/kg for o,p + p,p'-DDT, 0.008 mg/kg for p,p'-DDD and 0.005 mg/kg for p,p'-DDE. Consequently, these exceedences lead to restrictions on dredging activities and concerns over the toxicity of DDT compounds to the more sensitive species of sediment-dwelling organisms and possible biomagnification up through the food chain. In addition, the concentration of p,p'-DDT in Canagagigue Creek exceeded the OMOE 'severe effect level' sediment quality guideline of 71 mg/kg (based on total organic carbon content), a level above which pronounced disturbance of the sediment-dwelling community can be expected (Persaud et al., 1991).

Phytoplankton collected near Sarnia industrial discharges to the St. Clair River contained up to 13 mg/kg, dry weight of DDT, 27 mg/kg p,p'-DDD and 75 mg/kg p,p'-DDE (OMOE and MDNR, 1991). Net plankton from a variety of southern

Ontario lakes contained from 0.005 mg/kg to 0.084 mg/kg DDT, 0.0007 mg/kg to 0.184 mg/kg DDD and 0.003 mg/kg to 0.096 mg/kg DDE (Taylor et al., 1990).

The maximum wet weight concentrations of DDT or its metabolites in samples of benthic macroinvertebrates from the following areas were: 0.003 mg/kg p,p'-DDD and 0.002 mg/kg p,p'-DDE in oligochaetes from the St. Marys River (Jaagumagi et al., 1991c); 0.013 mg/kg p,p'-DDD in chironomids and 0.010 mg/kg p,p'-DDE in dragonfly larvae from Canagagigue Creek (Jaagumagi et al., 1991a); and 0.032 mg/kg p,p'-DDD and 0.051 mg/kg p,p'-DDE in oligochaetes from Toronto Harbour and from Humber Bay, respectively (EC, OMOE, OMNR and MTRCA, 1989). Emergent (adult) caddisflies or mayflies contained up to 0.027 mg/kg (dry weight) of p,p'-DDT in the Detroit River, and 0.001 mg/kg to 0.012 mg/kg in inland waters. In the same insects, mean levels of p,p'-DDE ranged as high as 0.036 mg/kg in the St. Clair River, 0.063 mg/kg in the Detroit River, and 0.022 mg/kg to 0.046 mg/kg in inland waters (Kovats and Ciborowski, 1989). Caged mussels exposed in the St. Clair and Detroit Rivers accumulated maximum mean concentrations of 0.004 mg/kg p,p'-DDE (Kauss and Hamdy, 1985).

Levels of DDT compounds ranged up: to 0.014 mg/kg o,p + p,p'-DDT, 0.004 mg/kg p,p'-DDD and 0.017 mg/kg p,p'-DDE in sculpin from the St. Marys River (Jaagumagi et al., 1991c); 0.219 mg/kg p,p'-DDE in minnows from Canagagigue Creek (Jaagumagi et al., 1991a); 0.005 mg/kg p,p'-DDD and 0.035 mg/kg p,p'-DDE in minnows from the Grand River (Jaagumagi et al., 1991b); and 0.012 mg/kg p,p'-DDD and 0.127 mg/kg p,p'-DDE in sculpin from Toronto (Jaagumagi et al., 1991d).

Total DDT concentrations in young-of-the-year spottail shiners from the Great Lakes and the St. Lawrence River declined significantly between the mid-1970's and the most recent (1986-1988) samples. Levels in all recent samples from Ontario Great Lakes waters are well below the GLWQA specific objective of 1.0 mg/kg (wet weight) for the protection of birds and animals which consume fish and also below the New York State criterion of 0.200 mg/kg (Newell et al., 1987). For example, the highest mean concentration in these fish during the period 1986-1988 was 0.091 mg/kg at the mouth of the Credit River in Lake Ontario (Suns et al., 1991).

Although DDT and its metabolites (mainly the metabolites) are still being detected in the edible portions of Ontario sport fish, principally in those from Lake Ontario, concentrations have decreased significantly since the late 1960s. In 1967, Lake Simcoe lake trout contained an average of 15.7 mg/kg 'total DDT' (DDT + metabolites). Since 1977, no sport fish samples have exceeded the Health and Welfare Canada guideline of 5.0 mg/kg for the protection of human consumers (Cox and Ralston, 1990). Currently, mean concentrations of 'total DDT' in lake trout from six major Ontario waterbodies are: 0.030 mg/kg (wet weight) in Lake Superior, 0.079 mg/kg in Lake Nipigon, 0.202 mg/kg in Lake Huron, 0.229 mg/kg in Lake Simcoe, 0.065 mg/kg in Lake Erie, and 1.230 mg/kg in Lake Ontario (Cox, pers. comm. Feb. 1991).

Dieldrin

Dieldrin is very persistent (Cox and Ralston, 1990). Dieldrin is still detectable in the aquatic environment, and in some areas its levels exceed criteria for water and sediment (Tables 2.4 and 2.5).

Lakewide mean water concentrations of dieldrin increase slightly from the upper to the lower Great Lakes: 0.287 ng/l in Lake Superior, 0.361 ng/l in Lake Huron, 0.321 ng/l in Georgian Bay, 0.367 ng/l in Lake Erie, and 0.310 ng/l in Lake Ontario (IJC, 1989). At the outlet of Lake Ontario to the St. Lawrence River, mean concentrations during 1987 ranged from 0.23 ng/l to 0.25 ng/l (Tsanis et al., 1989). Concentrations in some samples from Great Lakes nearshore areas have exceeded the PWQO of 1 ng/l for the protection of aquatic life (Table 2.5). These locations, with their maximum levels, include 3 ng/l in Port Weller Harbour (Jaagumagi and Persaud, 1992), 8 ng/l at the mouth of the Don River (Boyd, 1988) and 37 ng/l in Ashbridges Bay (Jaagumagi and Persaud, 1992), both in the Toronto area.

Dieldrin readily partitions onto particulate matter in water. For example, all of the loadings of dieldrin from tributaries discharging to the St. Clair River, Lake St. Clair and the Detroit River were associated with the suspended sediment phase. The maximum concentration of 0.088 mg/kg (dry weight) was recorded at the mouth of Talfourd Creek, a St. Clair River tributary (Johnson and Kauss, 1991). Maximum concentrations recorded in other Areas of Concern include 0.144 mg/kg in Thunder Bay (Boyd, 1990) and 0.115 mg/kg at the mouth of the Don River in Toronto (Boyd, 1988).

Surficial sediments contained up to 0.007 mg/kg (dry weight) of dieldrin in Thunder Bay (Boyd, 1990), 0.026 mg/kg in Peninsula Harbour (Jardine and Simpson, 1990), 0.104 mg/kg in the St. Marys River (Hesselberg and Hamdy, 1987), 0.008 mg/kg in Collingwood Harbour (Jaagumagi and Persaud, 1992), 0.004 mg/kg in Penetang Harbour (Jaagumagi and Persaud, 1992), 0.017 mg/kg in the St. Clair River (OMOE and MDNR, 1991), 0.037 mg/kg in the Niagara River (Creese, 1987), 0.011 mg/kg in Hamilton Harbour (OMOE, OMNR, OMAF, EC, FOC and RBG, 1989), 0.016 mg/kg, 0.100 mg/kg 0.007 mg/kg and 0.008 mg/kg in Toronto's Humber Bay, Ashbridges Bay, East Headland and Bluffer's Park, respectively (Jaagumagi and Persaud, 1992), 0.005 mg/kg in Frenchman's Bay (Jaagumagi and Persaud, 1992), 0.153 mg/kg in the Bay of Quinte (Poulton, 1990) and 0.029 mg/kg and 0.027 mg/kg, respectively, near Maitland and Cornwall in the St. Lawrence River (Wilkins, 1988; OMOE and EC, 1990). These values exceed the 'lowest effect level' sediment quality guideline of 0.002 mg/kg. Such exceedances therefore result in restrictions on open water disposal of dredged materials and concerns over the toxicity of dieldrin to the more sensitive species of sediment-dwelling organisms and possible biomagnification up through the food chain.

Maximum concentrations of dieldrin in samples of benthic macroinvertebrates were 0.003 mg/kg wet weight in oligochaetes from the St. Marys River (Jaagumagi et al., 1991c) and 0.008 mg/kg in leeches from Canagagigue Creek (Jaagumagi et al., 1991a). Emergent (adult) caddisflies or mayflies contained up to 0.020 mg/kg (dry weight) in the St. Clair River, 0.071 mg/kg in the Detroit River, and 0.004 mg/kg to

0.022 mg/kg in inland waters. Aldrin was detected at only a few of these locations, at a maximum of 0.0003 mg/kg (Kovats and Ciborowski, 1989). Although aldrin was not detected in sculpin from the St. Marys River at a method reporting limit of 0.001 mg/kg wet weight, levels of dieldrin ranged up to 0.015 mg/kg and 0.025 mg/kg (Jaagumagi et al., 1991c) and from Toronto (Jaagumagi et al., 1991d), respectively.

Dieldrin is not routinely analyzed for in Ontario young-of-the-year fish and sport fish samples. Aldrin, which is routinely analyzed for, is only present at non-detectable or low concentrations and is not a contaminant of concern in Ontario sport fish (Cox and Ralston, 1990).

1,4-Dichlorobenzene (Paradichlorobenzene)

This volatile organochlorine is used as a soil fumigant and pesticide, as well as in the manufacture of moth repellents, air deodorizers, dyes and their intermediates and pharmaceuticals (Verschueren, 1983).

Concentrations in water do not currently exceed available criteria (Tables 2.4 and 2.5). There are presently no criteria for safe concentrations in sediment or aquatic biota.

Lakewide mean concentrations of 1,4-dichlorobenzene in water increased from the upper to the lower Great Lakes in 1986: i.e., 0.332 ng/l in Lake Superior, 0.284 ng/l in Lake Huron and 0.377 ng/l in Georgian Bay, in contrast to 0.994 ng/l in Lake Erie and 1.462 ng/l in Lake Ontario (IJC, 1989). Still higher levels have been detected in nearshore areas, such as up to 42 ng/l downstream of a wastewater treatment plant in the Grand River (Oliver and Nicol, 1982). Although the mean concentration difference between the head and the mouth of the Niagara River in the dissolved and suspended sediment phases was only 1.6511 ng/l and 0.1812 ng/l (equivalent water concentration), respectively, this resulted in a significant increase between the inlet and outlet of the river in both the dissolved (1.0321 kg/d) and suspended sediment-associated (0.113 kg/d) daily loadings of 1,4-dichlorobenzene (Niagara River Data Interpretation Group, 1988).

Open lake mean surficial sediment concentrations of 1,4-dichlorobenzene also exhibit a major increase from the upper Great Lakes to Lake Ontario: i.e., 0.005 mg/kg (dry weight) in Lake Superior, 0.016 mg/kg in Lake Huron, 0.009 mg/kg in Lake Erie and 0.094 mg/kg in Lake Ontario. Maximum concentrations in Lake Superior and Lake Ontario were 0.009 mg/kg and 0.210 mg/kg, respectively (Oliver and Nicol, 1982).

Data on the concentrations of 1,4-dichlorobenzene in aquatic biota are relatively scarce. Phytoplankton from the nearshore of the upper St. Clair River contained up to 1600 mg/kg (dry weight) (OMOE and MDNR, 1991). Single samples of lake or rainbow trout from each of the Ontario Great Lakes contained low concentrations of 1,4-dichlorobenzene, ranging from "not detected' in Lake Superior to 0.004 mg/kg (wet weight) in Lakes Erie and Ontario (Oliver and Nicol, 1982).

3,3'-Dichlorobenzidine

This compound, also known as 3,3'-dichloro-4,4'-diaminobiphenyl, is used as an intermediate in the manufacture of azo pigments, a curing agent for isocyanate-terminated resins and for urethane resins (Verschueren, 1983).

There are no available criteria for safe concentrations of this organic compound in receiving water, sediment or aquatic biota. More importantly, the current lack of OMOE analytical methods for these matrices or for effluents precludes the ability to determine loadings of this compound or its environmental distribution and impact at this time.

Endosulfan (Thiodan)

This organochlorine pesticide is used in agriculture as a foliar insecticide on deciduous trees, vegetables, forage crops, grains and forest ornamentals. It is also used in termite control (deBarros, 1984). Technical grade endosulfan is composed of alpha and beta stereoisomers, of which the latter is more persistent (McEwen & Stephenson, 1979). Endosulfan sulphate is an important, highly persistent metabolite of endosulfan in aerobic soils (McEwen & Stephenson, 1979; Verschueren, 1983). Endosulfan compounds are still detected in the aquatic environment, and in some areas their levels exceed the criterion for water (Tables 2.4 and 2.5). There are presently no criteria for safe levels in sediment or aquatic biota.

Alpha- and beta-endosulfan were not found in water samples from Lakes Superior, Huron, Erie and Ontario and from Georgian Bay at the detection limit of 0.007 to 0.011 ng/l (IJC, 1989). However, the maximum concentrations of endosulfan compounds in some Areas of Concern or in the Great Lakes watershed exceeded the PWQO of 3 ng/l (Table 2.5). These include: 7 ng/l beta-endosulfan and 14 ng/l endosulfan sulphate in Thunder Bay (Boyd, 1990) and 10 ng/l in the Kaministikwia River, a major tributary (Jaagumagi & Persaud, 1992); 4 ng/l each of beta-endosulfan and endosulfan sulphate at the mouth of the Don River, a Toronto waterfront tributary (Boyd, 1988); and 7 ng/l in Oakville Harbour (Jaagumagi & Persaud, 1992). Monitoring data for 48 Ontario tributaries show that alpha-endosulfan, beta-endosulfan and endosulfan sulphate were present in 0.6%, 0.3% and 1.0%, respectively, of water samples collected in the period 1979 to 1982. Levels above the PWQO were present in 0.2%, 0.2% and 0.9% of the samples, respectively, (OMOE, unpubl. data). Concentrations of the alpha and beta isomers of up to 20 ng/l and 14 ng/l respectively, were found in Turkey Creek, a Detroit River tributary (Johnson & Kauss, 1991). Elevated concentrations of alpha- and beta-endosulfan have also been detected in the effluents of municipal sewage treatment plants (up to 90 ng/l and 56 ng/l, respectively) and of some industries (up to 116 ng/l and 40 ng/l, respectively) discharging to the Bay of Quinte area (Poulton, 1990).

Concentrations on suspended sediment in Thunder Bay ranged as high as 0.126 mg/kg, 0.058 mg/kg and 0.030 mg/kg (dry weight) of alpha-endosulfan, beta-endosulfan and endosulfan sulphate, respectively (Boyd, 1990). In the St. Clair River, the maximum concentrations of alpha-endosulfan, 0.026 mg/kg, and beta-endosulfan,

0.037 mg/kg, were found in the Cole Drain discharge (Johnson & Kauss, 1991). In the Toronto area, the maximum concentrations of 0.044 mg/kg alpha-endosulfan, 0.010 mg/kg beta-endosulfan and 0.032 mg/kg endosulfan sulphate were recorded at the mouths of Mimico Creek, the Humber River and the Don River, respectively, all Lake Ontario tributaries (Boyd, 1988).

Surficial sediments contain up to the following concentrations (dry weight) of endosulfan compounds: 0.010 mg/kg alpha-endosulfan, 0.004 mg/kg beta-endosulfan and 0.026 mg/kg endosulfan sulphate in Thunder Bay (Boyd, 1990; Jaagumagi & Persaud, 1992)); 0.012 mg/kg endosulfan sulphate in Peninsula Harbour (Jardine & Simpson, 1990); 0.039 mg/kg alpha-endosulfan, 0.021 mg/kg beta-endosulfan and 0.020 mg/kg endosulfan sulphate in the St. Marys River (Hesselberg & Hamdy, 1987; Jaagumagi & Persaud, 1992); 0.030 mg/kg, 0.026 mg/kg and 0.068 mg/kg of alpha-endosulfan, beta-endosulfan and endosulfan sulphate, respectively in tributaries to Collingwood Harbour (Beak, 1988a) as well as 0.031 mg/kg beta-endosulfan and 0.035 mg/kg endosulfan sulphate in Collingwood Harbour (Jaagumagi & Persaud, 1992); 0.019 mg/kg endosulfan sulphate in Midland Bay (Jaagumagi & Persaud, 1992); 0.010 mg/kg endosulfan sulphate in Penetang Harbour (Jaagumagi & Persaud, 1992); 0.005 mg/kg alpha- and beta-endosulfan in the Detroit River (Thornley & Hamdy, 1984); 0.003 mg/kg alpha-endosulfan in Lake Erie's Inner Long Point Bay (Ross & Hamdy, 1983); 0.005 mg/kg each of beta-endosulfan and endosulfan sulphate in the Grand River (Jaagumagi & Persaud, 1992); 0.016 mg/kg alpha-endosulfan in the Niagara River (Creese, 1987); 0.005 mg/kg beta-endosulfan and 0.060 mg/kg endosulfan sulphate in Toronto's Humber Bay (Jaagumagi & Persaud, 1992); 0.005 mg/kg beta-endosulfan in Rice Lake (Jaagumagi & Persaud, 1992); 0.033 mg/kg beta-endosulfan and 0.140 mg/kg endosulfan sulphate in the Bay of Quinte (Jaagumagi & Persaud, 1992); 0.027 mg/kg alpha-endosulfan near Maitland (Wilkins, 1988); and 0.004 mg/kg, 0.010 mg/kg and 0.022 mg/kg of alpha-endosulfan, beta-endosulfan and endosulfan sulphate, respectively, near Cornwall in the St. Lawrence River (OMOE & EC, 1990). There is currently no provincial criterion for safe levels of endosulfan compounds in sediments.

The maximum wet weight concentrations of endosulfan in samples of benthic macroinvertebrates from the following areas were: 0.002 mg/kg of the alpha isomer in oligochaetes from the St. Marys River (Jaagumagi et al., 1991c); 0.004 mg/kg in leeches and 0.009 mg/kg (both beta-endosulfan) in chironomid larvae from Canagagigue Creek (Jaagumagi et al., 1991a); 0.243 mg/kg beta-endosulfan in invertebrates from Ashbridges Bay near the Toronto Main STP and 0.006 mg/kg endosulfan sulphate in invertebrates from Humber Bay (Jaagumagi & Persaud, 1992); 0.002 mg/kg beta-endosulfan in chironomid larvae from Rice Lake (Jaagumagi & Petro, 1992).

Levels of endosulfan in fish ranged as high as 0.004 mg/kg alpha-endosulfan in juvenile fathead minnows exposed to Canagagigue Creek sediment (Jaagumagi et al., 1991a).

Endosulfan compounds are not routinely analyzed for in Ontario young-of-the-year fish and sport fish samples.

Endrin

This organochlorine pesticide is a stereoisomer of dieldrin (Verschueren, 1983). Its main use was as a foliar insecticide (McEwen & Stephenson, 1979). Endrin is still detectable in some samples from the aquatic environment, and in some areas its levels exceed the sediment quality criterion (Tables 2.4 and 2.5).

Of the five Great Lakes water bodies sampled, endrin was only detected in Lake Ontario water, with a lakewide mean concentration of 0.060 ng/l (IJC, 1989), which is below the PWQO of 2 ng/l for the protection of aquatic life. Monitoring data for 48 Ontario tributaries show that endrin was present in only 0.1% of water samples collected during the period 1979 to 1992 and concentrations were below the PWQO (OMOE, unpubl. data).

Endrin is found on particulate matter in water. For tributaries discharging to the St. Clair River, Lake St. Clair and the Detroit River, the maximum concentration of 0.120 mg/kg (dry weight) was recorded at the mouth of Baby Creek, a St. Clair River tributary (Johnson & Kauss, 1991). Maximum levels found in other Areas of Concern include 0.145 mg/kg in Thunder Bay (Boyd, 1990) and 0.030 mg/kg at the mouth of the Don River in Toronto (Boyd, 1988).

Surficial sediments contained up to: 0.013 mg/kg (dry weight) of endrin in Thunder Bay (Boyd, 1990); 0.046 mg/kg in Peninsula Harbour (Jardine & Simpson, 1990); 0.070 mg/kg in the St. Marys River (Jaagumagi & Persaud, 1992); 0.019 mg/kg in Collingwood Harbour (Jaagumagi & Persaud, 1992); 0.005 mg/kg in the Grand River (Jaagumagi & Persaud, 1992); 0.031 mg/kg in the Niagara River (Creese, 1987); 0.015 mg/kg in Hamilton Harbour (Jaagumagi & Persaud, 1992)); 0.040 mg/kg, 0.040 mg/kg, 0.035 mg/kg, 0.030 mg/kg and 0.013 mg/kg in Toronto's Humber Bay, Ashbridges Bay, Inner Harbour, Ashbridges Bay and East Headland, respectively (Jaagumagi & Persaud, 1992); 0.280 mg/kg in the Bay of Quinte (Jaagumagi & Persaud, 1992); and 0.100 mg/kg and 0.001 mg/kg, respectively, near Maitland and Cornwall in the St. Lawrence River (Wilkins, 1988; OMOE & EC, 1990). Most of these values exceed the 'lowest effect level' sediment quality guideline of 0.003 mg/kg. Such exceedences therefore result in concerns over the toxicity of endrin to the more sensitive species of sediment-dwelling organisms and possible biomagnification up through the food chain. Also, open water disposal of contaminated dredgate would be restricted.

The maximum wet weight concentrations of endrin in samples of benthic macroinvertebrates from the following areas were: 0.040 mg/kg in invertebrates from the Kaministikwia River, a tributary of Thunder Bay (Jaagumagi & Persaud, 1992); and 0.030 mg/kg in oligochaetes from Collingwood Harbour (OMOE & EC, 1989).

Endrin is not routinely analyzed for in Ontario young-of-the-year fish and sport fish samples.

Heptachlor and Heptachlor Epoxide

Technical heptachlor is composed of heptachlor and about 28% related compounds (Verschueren, 1983). Heptachlor exhibits strong bioaccumulative tendencies, and along with its principal metabolite heptachlor epoxide, can be highly toxic to aquatic life. Heptachlor epoxide, which is more acutely toxic and persistent than heptachlor, is also more frequently detected in the aquatic environment. In some areas, levels of heptachlor and/or heptachlor epoxide exceed criteria for water and sediment quality (Tables 2.4 and 2.5).

Lakewide mean water concentrations of heptachlor epoxide in the Great Lakes were: 0.124 ng/l in Lake Superior, 0.174 ng/l in Lake Huron, 0.170 ng/l in Georgian Bay, 0.162 ng/l in Lake Erie, and 0.107 ng/l in Lake Ontario, all below the PWQO of 1 ng/l for the protection of aquatic life. In contrast, heptachlor was not found in any samples at the detection limit of 0.007 to 0.011 ng/l (IJC, 1989). Concentrations in some samples from Great Lakes Basin or nearshore areas have exceeded the PWQO (Table 2.5). These locations, with their maximum levels, include: up to 11 ng/l in Thunder Bay (Boyd, 1990); 7 ng/l heptachlor in the St. Clair River (OMOE & MDNR, 1991); 2 ng/l heptachlor in Port Weller Harbour (Jaagumagi & Persaud, 1992); 7 ng/l heptachlor and 4 ng/l heptachlor epoxide in the Don River (Boyd, 1988). Monitoring data for 48 Ontario rivers and streams show that heptachlor and heptachlor epoxide were present in 0.4% and 2.0%, respectively, of water samples collected during the period 1979 to 1982. About 0.2% and 1.5%, respectively, of the samples contained levels above the PWQO (OMOE, unpubl. data). A maximum level of 2 ng/l heptachlor epoxide was found in the Thames River, Belle River and Pike Creek, all discharging to Lake St. Clair (Johnson & Kauss, 1991). Elevated concentrations of heptachlor and heptachlor epoxide have also been detected in the effluents of municipal sewage treatment plants (up to 50 ng/l of each compound) and of some industries (up to 70 ng/l of each) discharging to the Bay of Quinte area (Poulton, 1990).

Monitoring data provides evidence of the tendency of these compounds to partition onto the particulate matter in water. For example, for tributaries discharging to the St. Clair River, Lake St. Clair and the Detroit River the maximum level of 0.055 mg/kg heptachlor epoxide (dry weight) was recorded at the mouth of the Belle River, discharging to Lake St. Clair (Johnson & Kauss, 1991). Maximum concentrations found in other Areas of Concern include 0.006 mg/kg and 0.087 mg/kg of heptachlor and heptachlor epoxide, respectively in Thunder Bay (Boyd, 1990) and 0.035 mg/kg heptachlor epoxide at the mouth of Mimico Creek in Toronto (Boyd, 1988).

Surficial sediments contained up to the following concentrations (dry weight) of heptachlor compounds: 0.016 mg/kg heptachlor epoxide in the Kaministikwia River in Thunder Bay (Jaagumagi & Persaud, 1992); 0.009 mg/kg heptachlor epoxide in the St. Marys River (Hesselberg & Hamdy, 1987); 0.041 mg/kg heptachlor epoxide in the Hickory St. Canal, which discharges to Collingwood Harbour (Beak, 1988a) as well as 0.015 mg/kg in the Harbour (Jaagumagi & Persaud, 1992); 0.010 mg/kg, 0.040 mg/kg, 0.056 mg/kg and 0.010 mg/kg heptachlor epoxide in Toronto's Humber Bay, Ashbridges Bay, Inner Harbour and East Headland, respectively (Jaagumagi &

Persaud, 1992); 0.008 mg/kg heptachlor epoxide in Rice Lake (Jaagumagi & Petro, 1992); 0.045 mg/kg heptachlor epoxide in the Bay of Quinte (Jaagumagi & Persaud, 1992); and 0.010 mg/kg heptachlor epoxide near Cornwall in the St. Lawrence River (OMOE & EC, 1990). These values exceed the 'lowest effect level' sediment quality guideline of 0.003 mg/kg for heptachlor epoxide. Such exceedences therefore result in concerns over the toxicity of this organochlorine to the more sensitive species of sediment-dwelling organisms and possible biomagnification up through the food chain. Also, open water disposal of contaminated dredgate would be restricted.

In benthic organisms, maximum wet weight concentrations of these compounds were: 0.003 mg/kg heptachlor epoxide in oligochaetes from Collingwood Harbour (OMOE & EC, 1989); 0.006 mg/kg heptachlor in invertebrates from Canagagigue Creek (Jaagumagi & Persaud, 1992); 0.025 mg/kg, 0.012 mg/kg and 0.006 mg/kg heptachlor in invertebrates from Toronto's East Headland, Harbour and Ashbridges Bay areas, respectively (Jaagumagi & Persaud, 1992); 0.007 mg/kg heptachlor epoxide in chironomid larvae from Rice Lake (Jaagumagi & Petro, 1992); and 0.034 mg/kg heptachlor epoxide in invertebrates from the St. Lawrence River (Jaagumagi & Persaud, 1992). Burrowing mayfly larvae and juvenile fathead minnows exposed to Rice Lake sediments in the laboratory accumulated 0.002 mg/kg heptachlor and 0.008 mg/kg heptachlor epoxide, respectively. Burrowing mayfly larvae exposed to Canagagigue Creek sediments accumulated 0.007 mg/kg heptachlor and 0.010 mg/kg heptachlor epoxide (Jaagumagi et al., 1991a). Emergent (adult) caddisflies or mayflies contained up to 0.0006 mg/kg (dry weight) heptachlor in the Detroit River, and up to 0.001 mg/kg in inland waters. Heptachlor epoxide was found at higher levels and at more of the sampling locations: a maximum of 0.009 mg/kg in the St. Clair River; 0.021 mg/kg in the Detroit River; and 0.008 mg/kg in inland waters (Kovats & Ciborowski, 1989). Heptachlor in sculpin from the St. Marys River only reached a maximum of 0.001 mg/kg wet weight, while levels of heptachlor epoxide of up to 0.005 mg/kg were detected; juvenile fathead minnows exposed to sediment from one location in the river accumulated up to 0.019 mg/kg heptachlor epoxide (Jaagumagi et al., 1991c). In contrast, sculpin from one location in the Otonabee River contained up to 0.014 mg/kg heptachlor and juvenile fathead minnows exposed to sediment from Rice Lake accumulated up to 0.008 mg/kg heptachlor epoxide (Jaagumagi & Petro, 1992).

Heptachlor is routinely analyzed for in Ontario young-of-the-year fish and sport fish samples, but is only present at non-detectable or low concentrations (below the GLWQA objective of 0.3 mg/kg for the protection of human consumers of fish) and is not a contaminant of concern in Ontario sport fish (Cox & Ralston, 1990).

## Hexachlorobenzene

In Ontario, hexachlorobenzene contamination is perhaps largely a byproduct of the electrolytic production of chlorine and of certain chlorinated solvents (Kauss and Hamdy, 1985). However, this chlorinated aromatic compound has also been used as: a fungicide for seed treatment of cereal grains prior to planting; as a wood preservative; in fluorocarbon and synthetic rubber production; a plasticizer for polyvinyl chloride; in the manufacture of pyrotechnics; and as a fluxing agent in

aluminum smelting. Other possible sources of contamination are related to its creation as a byproduct during the manufacture of vinyl chloride monomer, certain pesticides such as atrazine and pentachlorophenol, and of sodium chlorate (debarros, 1984; Verschueren, 1983).

This contaminant has been detected in water, sediment or biota samples from most Great Lakes Areas of Concern. Concentrations in some samples exceed available criteria for these components of the aquatic ecosystem (Tables 2.4 and 2.5).

Lakewide mean concentrations of hexachlorobenzene in water increase gradually as one progresses down through the Great Lakes: 0.025 ng/l in Lake Superior, 0.029 ng/l in Lake Huron, 0.041 ng/l in Georgian Bay, 0.054 ng/l in Lake Erie, and 0.057 ng/l in Lake Ontario (IJC, 1989). While these average levels do not exceed the PWQO of 6.5 ng/l for the protection of aquatic life, concentrations in some nearshore Areas of Concern do. These include the maxima of 8 ng/l in Thunder Bay and 7 ng/l in Toronto Harbour (Jaagumagi and Persaud, 1992). Although 1984 concentrations along the Sarnia shore of the St. Clair River reached as high as 2400 ng/l, more recent (1986) concentrations in water have been lower, with a maximum of 210 ng/l being reported (OMOE and MDNR, 1991). Nevertheless, the latter is still well above the PWQO. Lower levels of 0.31 to 0.33 ng/l were found in the Detroit River in 1986 (MDNR and OMOE, 1991). In the Niagara River, hexachlorobenzene was detected in the dissolved phase at Niagara-on-the-Lake at a mean concentration of 0.1202 ng/l, but not at Fort Erie. This resulted in a significant increase between the head and the mouth of the river in the daily loading (0.075 kg/d) of this compound (Niagara River Data Interpretation Group, 1988).

Elevated levels of hexachlorobenzene have also been detected in the suspended sediment fraction of water near or downstream of sources. In the St. Clair and Detroit Rivers, maximum concentrations in this phase were 0.535 mg/kg and 0.019 mg/kg (dry weight), respectively. Based on these 1984 data, the estimated net daily loading increase between the head and the mouth of the St. Clair River was 0.780 kg/d, and 0.204 kg/d for the Detroit River (Johnson and Kauss, 1987). In the Niagara River, the significant sediment-associated loading increase of 0.104 kg/d between the head and the mouth was related to a concentration difference of only 0.1661 ng/l (equivalent water concentration) (Niagara River Data Interpretation Group, 1988). In the Toronto area, a maximum of 0.027 mg/kg was detected in the Don River, a tributary of Lake Ontario (Boyd, 1988). Lake Ontario suspended sediment samples contained a mean concentration of 0.014 mg/kg (Oliver, 1984).

Mean open lake surficial sediment concentrations of hexachlorobenzene also exhibit a major increase from the upper Great Lakes to Lake Ontario: i.e., 0.0002 mg/kg (dry weight) in Lake Superior, 0.002 mg/kg in Lake Huron, 0.003 mg/kg in Lake Erie and 0.097 mg/kg in Lake Ontario. Maximum concentrations in Lake Superior and Lake Ontario were 0.0007 mg/kg and 0.320 mg/kg, respectively (Oliver and Nicol, 1982). Maximum concentrations in a number of waterbodies are below the OMOE 'no effect level' sediment quality guideline of 0.01 mg/kg. These include Lakes Superior, Huron and Erie and such areas of concern as Thunder Bay with 0.005 mg/kg (Boyd, 1990), and Hamilton Harbour with 0.007 mg/kg (OMOE, OMNR, OMAF, EC, FOC and RBG, 1989). Concentrations in other areas, such as the mean in Lake Ontario

(see above), and the maxima of 0.034 mg/kg in Peninsula Harbour (Jardine and Simpson, 1990), 0.047 mg/kg in Collingwood Harbour (Jaagumagi and Persaud, 1992), 0.028 mg/kg in the Detroit River (Thornley and Hamdy, 1984), 0.076 mg/kg in the Niagara River (Creese, 1987), and 0.590 mg/kg in the Bay of Quinte (Poulton, 1990) exceed the OMOE 'lowest effect level' sediment quality guideline of 0.02 mg/kg. Consequently, there is concern regarding hexachlorobenzene toxicity to the more sensitive species of sediment-dwelling organisms and its possible biomagnification up through the food chain. Furthermore, sediments from some sampling locations downstream of known sources contain hexachlorobenzene levels exceeding the OMOE 'severe effect level' sediment quality guideline (Table 2.4), a level above which pronounced disturbance of the sediment-dwelling community can be expected (Persaud et al., 1991). These include the St. Clair River, with levels up to 3.28 mg/kg in 1985 (OMOE and MDNR, 1991) and up to 45.50 mg/kg in 1990 (OMOE, unpublished 1990 data) and the St. Lawrence River near Maitland, with up to 0.351 mg/kg (Wilkins, 1988). These exceedences also indicate restrictions on dredging activities.

Phytoplankton collected near Sarnia organic chemical industry discharges to the St. Clair River contained up to 2700 mg/kg (dry weight) of hexachlorobenzene (OMOE and MDNR, 1991). Mean concentrations in Cladophora from the river ranged up to 0.050 mg/kg; mean concentrations in aquatic macrophytes from the river varied with species and location, with a maximum of 0.038 mg/kg in the macrophyte Potamogeton gramineus (St. Clair River MISA Pilot Site Team, 1991). Oligochaetes from Toronto's Eastern Waterfront sediments contained up to 0.070 mg/kg (wet weight) of hexachlorobenzene (EC, OMOE, OMNR and MTRCA, 1989). The highest concentrations accumulated by caged freshwater mussels exposed along the Ontario shore of St. Clair River in 1984 were 0.551 mg/kg (wet weight) (OMOE and MDNR, 1991), and 0.004 mg/kg in the Detroit River (OMOE, unpublished 1984 data). In 1986, the maximum hexachlorobenzene level accumulated by caged mussels in the St. Clair River was 0.035 mg/kg (OMOE and MDNR, 1991). Concentrations in native burrowing mayfly larvae from the same river ranged up to 0.126 mg/kg (dry weight) and were positively correlated to levels in the sediment (OMOE and MDNR, 1991). Emergent (adult) caddisflies or mayflies contained up to 0.222 mg/kg (dry weight) in the St. Clair River and 0.120 mg/kg in the Detroit River, compared to 0.0008 mg/kg to 0.0019 mg/kg in inland waters (Ciborowski and Corkum, 1988; Kovats and Ciborowski, 1989).

Except for locations close to sources, concentrations of hexachlorobenzene in young-of-the-year spottail shiners are normally low or non-detectable. This is shown by recent (1985-1988) data from numerous nearshore collection sites in the Great Lakes. The maximum mean concentration at any Ontario site in Lake Superior was 0.004 mg/kg (wet weight), 'not detected' in the St. Marys River, 0.005 mg/kg in Lake Huron, 0.060 mg/kg in the St. Clair River, 0.010 mg/kg in Lake St. Clair, 0.011 mg/kg in the Detroit River, 0.004 mg/kg in Lake Erie, 0.004 mg/kg in the Niagara River, 0.010 mg/kg in Lake Ontario and 0.005 mg/kg in the St. Lawrence River. While these are all below the New York State criterion of 0.33 mg/kg for the protection of fish-eating birds, a concentration of 0.780 mg/kg was detected near a source along the U.S. side of the Niagara River in 1984 (Suns et al., 1991). Concentrations of hexachlorobenzene in sculpin from the St. Clair River ranged up to

0.018 mg/kg (wet weight), in contrast to the maximum of 0.003 mg/kg in sculpin from the control location (OMOE and MDNR, 1991). Sculpin from Collingwood Harbour contained up to 0.010 mg/kg (OMOE and EC, 1989).

Presently, there is no federal human consumption guideline for fish; however, the USEPA has established a draft guideline of 0.0064 mg/kg for hexachlorobenzene. Mean concentrations in dorsal fillets of channel catfish from Lake Huron slightly exceeded this value during 1984 and 1985, whereas Lake St. Clair catfish greatly exceeded this value during the period 1979 to 1986 (OMOE and MDNR, 1991).

Detectable levels of hexachlorobenzene are also present in the higher trophic levels of the Great Lakes ecosystem. These include waterfowl, piscivorous birds and snapping turtles (Allan et al., 1991). For example, mean concentrations in the breast muscle of non-migratory mallard and redhead ducks from Walpole Island in the lower St. Clair River (0.007 mg/kg and 0.011 mg/kg, respectively) were higher than in the corresponding migratory duck samples (0.005 mg/kg and 0.002 mg/kg, respectively) (OMOE and MDNR, 1991).

alpha-1,2,3,4,5,6-Hexachlorocyclohexane

This organochlorine contaminant is also known as alpha-BHC and is a constituent of technical grade BHC. Technical grade BHC contains a mixture of alpha, beta, gamma (lindane), delta and epsilon isomers in the amounts of about 5:0.5:1:0.25:trace (deBarros, 1984).

Water and sediments in some areas exceeded available criteria (Tables 2.4 and 2.5). There are presently no numerical criteria for safe concentrations of alpha-BHC in aquatic biota. However, the GLWQA states that contaminants such as this should not be detectable (IJC, 1987).

The alpha isomer is considered to be ubiquitous in Great Lakes Basin waters. During the period 1984-1988, alpha-BHC was detected at 55 of 66 river and stream monitoring sites in Ontario, and 48% of the samples contained concentrations above the 1 ng/l analytical method minimum reporting limit (Whitehead, 1991). Mean concentrations in the Great Lakes range from 3.823 ng/l in Lake Erie to 7.840 ng/l in Lake Superior (IJC, 1989). Concentrations in the dissolved phase of water samples from the St. Clair River were similar, with a range of 'not detected' to 6.650 ng/l (OMOE and MDNR, 1991). At the outlet of Lake Ontario to the St. Lawrence River, mean concentrations in water during 1987 ranged from 2.76 ng/l north of, to 3.70 ng/l south of Wolfe Island (Tsanis et al., 1989).

Locally elevated concentrations in water samples of up to 21 ng/l and 159 ng/l, respectively, have been detected in Peninsula Harbour (Jardine and Simpson, 1990) and in the Niagara River near U.S. sources of contamination (MOE, unpublished 1983 data). These values exceed the NYSDEC ambient water quality criterion of 10 ng/L for the protection of aquatic life. Elevated concentrations have also been detected in the effluents of municipal sewage treatment plants (up to 100 ng/l) and of some industries (up to 30 ng/l) discharging to the Bay of Quinte area (Poulton, 1990).

In the Niagara River, the mean suspended sediment-associated loading of 0.014 kg/d increased significantly between Fort Erie and Niagara-on-the-Lake during the period 1986-1987, and was due to a concentration difference of 0.0225 ng/l (equivalent water concentration) (Niagara River Data Interpretation Group, 1988). In the Toronto area, the maximum of 0.017 mg/kg (dry weight) on suspended sediments was detected in Mimico Creek, a tributary of Lake Ontario (Boyd, 1988).

Surficial sediment levels of this organochlorine, when detected, are normally quite low, and near or below the OMOE 'lowest effect level' sediment quality guideline of 0.006 mg/kg. For example, maximum concentrations were 0.001 mg/kg (dry weight) in Thunder Bay (Boyd, 1990), 0.002 mg/kg in Peninsula Harbour (Jardine and Simpson, 1990), 0.003 mg/kg in Collingwood Harbour (Beak, 1988a), 0.007 mg/kg in the St. Clair River (OMOE, unpublished 1985 data) and 0.006 mg/kg in Hamilton Harbour (Poulton, 1986). In contrast, levels markedly exceeding the above guideline have been found in the Detroit River (0.014 mg/kg) and near U.S. sources to the Niagara River (0.0612 mg/kg) (Jaagumagi and Persaud, 1992). Therefore, there would be concern over the toxicity of this compound to the more sensitive species of sediment-dwelling organisms, its possible biomagnification in the food chain and open water disposal of contaminated sediments (Persaud et al., 1991).

Concentrations of this compound in biota are usually low. For example, levels in net plankton collected from 33 southern Ontario lakes ranged from 0.0003 mg/kg to 0.0125 mg/kg (dry weight) (Taylor et al., 1990). In contrast, phytoplankton samples from the St. Clair River near industrial discharges contained from 2 to 18 mg/kg (OMOE and MDNR, 1991). Oligochaetes from sediments of Toronto's Humber Bay contained up to 0.031 mg/kg (wet weight) (EC, OMOE, OMNR and MTRCA, 1989). Emergent (adult) caddisflies and mayflies contained up to 0.014 mg/kg (dry weight) in the St. Clair River and 0.017 mg/kg in the Detroit River, compared to 0.001 mg/kg to 0.008 mg/kg in inland waters (Kovats and Ciborowski, 1989). The maximum concentration in adult sculpin from Collingwood Harbour was 0.004 mg/kg (wet weight) (OMOE and EC, 1989). (also see below re 'total BHCs' in young-of-the-year spottail shiners).

gamma-1,2,3,4,5,6-Hexachlorocyclohexane (Lindane)

Use of BHC was restricted in the 1970s (Cox and Ralston, 1990). However, lindane is still used on a limited basis for seed and soil treatment, foliar applications on fruit trees, vegetables and ornamentals, for wood protection (debarros, 1984) and as a scabicide (Verschueren, 1983).

This pesticide has been detected in water, sediment or biota samples from most Great Lakes Areas of Concern. Concentrations in some samples exceed available criteria for water and sediment (Tables 2.4 and 2.5).

Similarly to the alpha isomer, the gamma isomer is present throughout the Great Lakes Basin, but is usually found at lower concentrations in water. Lakewide mean concentrations in the Great Lakes range from 0.671 ng/l in Georgian Bay to

1.250 ng/l in Lake Ontario (IJC, 1989). At the outlet of Lake Ontario to the St. Lawrence River, mean concentrations during 1987 ranged from 0.56 ng/l to 0.75 ng/l (Tsanis et al., 1989). Higher concentrations have been detected in the nearshore close to urban-industrial complexes. Examples, with their maximum levels include 3 ng/l in Peninsula Harbour (Jardine and Simpson, 1990), 14 ng/l in the St. Clair River (Jaagumagi and Persaud, 1992), 4 ng/l in the Detroit River (Kauss and Hamdy, 1985), 45 ng/l in Canagagigue Creek (Jaagumagi et al., 1991a), in 59 ng/l in Hamilton Harbour (Poulton, 1986) and 89 ng/l at the mouth of the Don River in Toronto (Boyd, 1988). The St. Clair River, Hamilton and Toronto maxima exceed the PWQO and the GLWQA objective of 10 ng/l for the protection of aquatic life. Elevated levels have also been detected in effluents of municipal sewage treatment plants (up to 185 ng/l) and of some industries (up to 25 ng/l) in the Bay of Quinte area (Poulton, 1990).

In the Toronto area, a maximum of 0.015 mg/kg (dry weight) was associated with the suspended sediment fraction in the Don River, a Lake Ontario tributary at Toronto (Boyd, 1988).

Except near some point sources or hazardous waste sites, this organochlorine pesticide is not frequently detected in surficial sediment samples. However, since the OMOE minimum reporting limit is 0.001 mg/kg, it is difficult to determine what proportion of sediment samples exceed the OMOE 'no effect level' sediment quality guideline of 0.0002 mg/kg. Those occasional samples with detectable levels can slightly exceed the OMOE 'lowest effect level' guideline of 0.003 mg/kg. These include the maximum concentrations of 0.005 mg/kg (dry weight) in the St. Clair River (OMOE and MDNR, 1991), 0.004 mg/kg in Collingwood Harbour (Beak, 1988), 0.007 mg/kg in Canagagigue Creek (Jaagumagi et al., 1991a) and 0.008 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992). These levels cause concern over lindane toxicity to the more sensitive species of sediment-dwelling organisms and its possible biomagnification up through the food chain (Persaud et al., 1991). Also, open water disposal of contaminated dredgate would be restricted.

Concentrations of lindane in biota are generally low or non detectable. For example, levels in net plankton from different southern Ontario lakes ranged from 0.0006 mg/kg to 0.0145 mg/kg (dry weight) (Taylor et al., 1990). Oligochaetes from sediments of Toronto Harbour contained a maximum of 0.015 mg/kg (wet weight) (EC, OMOE, OMNR and MTRCA, 1989). Emergent (adult) caddisflies and mayflies contained a maximum of 0.006 mg/kg (dry weight) in the St. Clair River and 0.013 mg/kg in the Detroit River, compared to 0.0005 mg/kg to 0.004 mg/kg in inland waters (Kovats and Ciborowski, 1989). Low concentrations are also exemplified by recent (1985-1988) data on 'total BHCs' (which includes the alpha, beta and gamma isomers of hexachlorocyclohexane) in young-of-the-year spottail shiners from various nearshore collection sites in the Great Lakes. Overall, BHCs were 'not detected' at all sites in Lake Superior, the St. Marys River, Lake Huron, the St. Clair River, Lake St. Clair, the Detroit River, Lake Erie and the St. Lawrence River, and in Lake Ontario fish only reached 0.002 mg/kg (wet weight). However, a mean concentration of 0.267 mg/kg (wet weight) was found in fish collected near a source on the U.S. side of the Niagara River (Suns et al., 1991). This exceeds the New York

State criterion of 0.1 mg/kg for the protection of fish-eating birds (Newell et al., 1987).

Concentrations of lindane in the edible portion of Ontario sport fish are below the GLWQA specific objective of 0.3 mg/kg for the protection of human consumers.

Mercury

Mercury occurs naturally in bedrock and fossil fuels such as coal. This element has been used, either in its elemental form or as organic compounds in: chlorine production; the manufacture of batteries, switches, thermometers, barometers and mercury vapour lamps; gold and silver mining; slimicides; fungicides for paints, coatings and golf greens; and in dental filling amalgams. Due to restrictions in the late 1960s and early 1970s, losses to the aquatic environment from industrial point sources have decreased significantly (Cox and Ralston, 1990; deBarros, 1984).

The presence of mercury in the ecosystem has resulted in beneficial use impairments throughout the Great Lakes and in many inland waters due to exceedances of criteria for water, sediment or biota (Tables 2.4 and 2.5).

Mercury concentrations in open waters are very low. For example, the median dissolved and particulate-associated levels for the Great Lakes were 0.00 µg/l and 0.0010 µg/l in Lake Superior, 0.0042 µg/l in Lake Huron (no particulate data), 0.024 µg/l and 0.00020 µg/l in Lake Erie and 0.011 µg/l and 0.00020 µg/l in Lake Ontario (Rossman and Barres, 1988). Nevertheless, in occasional whole water samples from localized areas, levels of mercury have exceeded the PWQO and the GLWQA objective of 0.2 µg/l for the protection of aquatic life. These locations, with their maximum levels, include 0.36 µg/l in the Nipigon River (OMOE, EC, OMNR and F&OC, 1991a), 0.48 µg/l in the St. Marys River (Jaagumagi et al., 1991c), 0.21 µg/l in the St. Clair River (Jaagumagi and Persaud, 1992), 0.31 µg/l in Wheatly Harbour (OMOE, EC, OMNR and OMAF, 1990), 0.23 µg/l in Port Weller Harbour(Jaagumagi and Persaud, 1992), 0.26 µg/l in Hamilton Harbour (Poulton, 1986), 0.31 µg/l, 0.34 µg/l and 0.25 µg/l in Toronto's Humber Bay, Inner Harbour and East Headland areas (Jaagumagi and Persaud, 1992), 0.24 µg/l in the Bay of Quinte (Jaagumagi and Persaud, 1992). Concentrations of up to 0.449 µg/l were found in the Trenton Channel on the Michigan side of the Detroit River (MDNR and OMOE, 1991).

Concentrations of mercury associated with the suspended sediment phase of water were as high as 0.34 mg/kg (dry weight) in Thunder Bay (Boyd, 1990), 0.40 mg/kg in the St. Clair River, 0.47 mg/kg in the Detroit River (Johnson and Kauss, 1987), 1.00 mg/kg in Talfourd Creek, a tributary of the St. Clair River (Johnson and Kauss, 1991), 10.00 mg/kg adjacent to a lakefilling area in Toronto's Outer Harbour (Boyd, 1988), and up 0.23 mg/kg in the St. Lawrence River near Cornwall (OMOE and EC, 1990). A net increase in the mean daily loading between the head and mouth of both the St. Clair River (6.61 kg/d) and the Detroit River (6.60 kg/d) was calculated based on the above data (Johnson and Kauss, 1987).

Surficial sediments contained up to 0.66 mg/kg (dry weight) in Thunder Bay (Boyd, 1990), 8.80 mg/kg in Peninsula Harbour (Jardine and Simpson, 1990), 0.23 mg/kg in Jackfish Bay (Beak, 1988b), 0.38 mg/kg in the St. Marys River (Hesselberg and Hamdy, 1987), 1.00 mg/kg in Midland Bay (OMOE, EC, OMNR and OMAF, 1988), 1.00 mg/kg in Collingwood Harbour (Jaagumagi, 1988), 1.00 mg/kg in Midland Harbour (Jaagumagi, 1988), 51.00 mg/kg in the St. Clair River (OMOE and MDNR, 1991), 0.62 mg/kg in the Detroit River (Thornley and Hamdy, 1984), 1.20 mg/kg in the Niagara River (Creese, 1987), 0.48 mg/kg in Hamilton Harbour (Jaagumagi and Persaud, 1992), 0.22 mg/kg in Oakville Harbour (Jaagumagi, 1988), 0.86 mg/kg, 2.60 mg/kg, 8.50 mg/kg and 0.33 mg/kg in Toronto's Humber Bay, Inner Harbour, Ashbridges Bay and East Headland, respectively (Jaagumagi, 1988, Jaagumagi et al., 1991d), 0.32 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992), 0.73 mg/kg in the Bay of Quinte (Jaagumagi, 1988), and 0.47 mg/kg and 4.40 mg/kg, respectively, near Maitland and near Cornwall in the St. Lawrence River (Wilkins, 1988; OMOE and EC, 1990). Most of these values exceed the 'lowest effect level' sediment quality guideline of 0.2 mg/kg. Based on the latter guideline, there is concern regarding mercury toxicity to the more sensitive species of sediment-dwelling organisms and possible biomagnification through the food chain. Furthermore, the Peninsula Harbour, St. Clair River, Toronto (Inner Harbour and Ashbridges Bay) and Cornwall maxima exceed the OMOE 'severe effect level' guideline of 2 mg/kg, a level above which pronounced disturbance of the sediment-dwelling community can be expected (Persaud et al., 1991). These exceedences also indicate restriction on dredging activities or open water disposal of contaminated sediments.

Mercury concentrations in the filamentous alga Cladophora ranged up to 0.13 mg/kg (dry weight) in the Niagara River (OMOE, EC, OMNR and F&OC, 1991c), almost three times the maximum of 0.05 mg/kg reported for Wheatly Harbour (OMOE, EC, OMNR and OMAF, 1991). Oligochaetes from Toronto Harbour sediments contained up to 0.081 mg/kg (wet weight) of mercury (EC, OMOE, OMNR and MTRCA, 1989). Oligochaetes, chironomids and amphipods from Collingwood Harbour sediments contained up to 0.206 mg/kg, 0.101 mg/kg and 0.218 mg/kg, respectively (OMOE and EC, 1989). Burrowing mayfly larvae exposed to contaminated Hamilton Harbour sediments accumulated up to 0.22 mg/kg, in contrast to the control culture organisms, which contained a maximum of 0.09 mg/kg (Krantzberg,1991).

Mercury is detectable in most young-of-the-year spottail shiner collections from the Great Lakes; however, concentrations do not presently exceed the GLWQA objective of 0.5 mg/kg (wet weight) in whole fish for the protection of aquatic life and fish-eating birds. Furthermore, significant declines in mercury levels were recorded in the Big Creek, Leamington and the Grand River (in Lake Erie) and the Niagara-on-the-Lake (in the Niagara River) collection sites between the mid to the late 1970s. Levels have, however, remained virtually unchanged since then (Suns et al., 1985). The maximum mercury concentration in adult sculpin from Collingwood Harbour was 0.086 mg/kg (OMOE and EC, 1989).

Although mercury levels have also declined in sport fish at some locations in recent years (OMOE and OMNR, 1991), restricted human consumption advisories for larger sizes of various species are still widespread throughout the Great Lakes and Ontario's inland waters. These are related to mercury concentrations above the

Health and Welfare Canada objective of 0.5 mg/kg. Such areas include Thunder Bay, Nipigon Bay, Jackfish Bay, Peninsula Harbour, St. Marys River, Spanish River, Georgian Bay, Lake Huron, St. Clair River, Lake St. Clair, Detroit River, Lake Erie, Niagara River, Lake Ontario, Bay of Quinte, the St. Lawrence River at Cornwall and the English-Wabigoon system (OMOE and OMNR, 1991).

Mercury is also present at elevated concentrations in the higher trophic levels of the Great Lakes ecosystem, such as waterfowl and piscivorous birds (Allan et al., 1991).

Mirex

Mirex was manufactured in Niagara Falls, New York and was primarily used as an insecticide to control fire ants in the southern United States. However, it was also used as fire retardant in plastics, electronic components, caulking and in fabrics, and was imported into southern Ontario by two companies for use in their manufactured plastic products. The use of mirex was banned in 1978 by the USEPA (Cox and Ralston, 1990; deBarros, 1984).

The main sources of mirex are located in New York State in the Niagara River and in the Oswego River, both of which are tributaries of Lake Ontario. This has led to exceedances of sediment and biota criteria and consequently, use impairments in this lake and in downstream areas in the St. Lawrence River.

Although locally elevated concentrations of up to 20 ng/l have in the past been detected in the upper Niagara River near U.S. sources (MOE, unpublished 1983 data), concentrations of this organochlorine contaminant in water do not currently exceed the PWQO for the protection of aquatic life of 1 ng/l. On the other hand, levels in some sediments and fish from the Niagara River and from Lake Ontario exceed the OMOE sediment quality guideline and the GLWQA objective for the protection of higher trophic levels (Tables 2.4 and 2.5).

In the Niagara River, the suspended sediment-associated loading of 0.014 kg/d increased significantly between Fort Erie and Niagara-on-the-Lake and was due to a concentration of 0.0217 ng/l (equivalent water concentration) at the outlet of the river (Niagara River Data Interpretation Group, 1988).

Maximum surficial sediment concentrations of mirex were usually less than the 0.005 mg/kg (dry weight) minimum reporting limit in sediments from Ontario waters of the lower Niagara River, but ranged up to 0.055 mg/kg (Creese, 1987). Mean surficial sediment levels in the Niagara and Oswego anomalies of Lake Ontario were 0.024 mg/kg and 0.012 mg/kg with maxima of 0.043 mg/kg and 0.019 mg/kg, respectively in 1976 (Holdrinet et al., 1978). Mirex has also been detected at low levels in Toronto's Humber Bay with a maximum of 0.010 mg/kg (Jaagumagi and Persaud, 1992) and downstream of Cornwall in the Lake St. Francis section of the St. Lawrence River at 0.003 mg/kg (Sloterdijk, 1991). In contrast, levels of up to 0.985 mg/kg have been found near U.S. hazardous waste sites in the upper Niagara River (Creese, 1987). Of the above, those concentrations exceeding the OMOE 'lowest effect level' sediment quality guideline of 0.007 mg/kg would result in restrictions on

dredging activities and concern over the toxicity of this contaminant to the more sensitive species of sediment-dwelling organisms and its possible biomagnification in the food chain (Persaud et al., 1991).

Mirex was not detected in the filamentous green alga Cladophora collected along the Ontario shore of the Niagara River in 1987, but concentrations of up to 0.263 mg/kg (dry weight) were found in samples from the New York State shoreline above the Falls. This was also the case for caged mussels exposed in the river for three weeks, with mirex only being detected at a Niagara Falls, N.Y. site, at 0.167 mg/kg (Anderson et al., 1991).

Mirex was only detected (i.e., above 5 µg/kg) in young-of-the-year spottail shiners in some years from some Niagara River, Lake Ontario and lower St. Lawrence River collection sites and therefore exceeded the GLWQA objective of substantially absent or non-detectable, for the protection of birds and animals which consume fish (Suns et al., 1991). This indicates a potential for reproductive toxicity in higher trophic levels. These locations included: Niagara-on-the-Lake in the Niagara River; and at the Welland Canal, Twelve Mile Creek, Burlington Beach, Bronte Creek, Credit River and Wolfe Island in Lake Ontario. The highest concentration in any of these recent collections was 0.008 mg/kg (wet weight) at Niagara-on-the-Lake and 0.037 mg/kg at the mouth of the Credit River (Suns et al., 1991).

While significant declines have occurred in recent years at many Lake Ontario collection sites, mirex concentrations in fish from some locations in the western end of the lake, such as the Credit River, continue to be elevated (Cox and Ralston, 1990). In fact, mirex is still the contaminant which results in the most human consumption restrictions for Lake Ontario sport fish with a high fat content, such as salmonids, carp and catfish. For example, dorsal fillets of Lake Ontario lake trout contain a mean mirex concentration of 0.221 mg/kg, with a minimum and maximum of 0.117 mg/kg and 0.631 mg/kg, respectively. These concentrations all exceed the Health and Welfare Canada guideline for human consumption of 0.1 mg/kg (wet weight). In addition, mirex levels in larger sizes of recently-collected white sucker and walleye from the St. Lawrence River near Cornwall have also exceeded the guideline and have therefore resulted in limited consumption advisories (OMOE and EC, 1990).

## Pentachlorophenol

Pentachlorophenol is mainly used as a preservative in the lumber and leather tanning industry (deBarros, 1984).

Pentachlorophenol has been detected in some Ontario inland surface waters and Areas of Concern, and in certain cases, concentrations exceed available water criteria (Tables 2.4 and 2.5). There is presently no criterion for sediments.

Reported levels of pentachlorophenol in water range as high as 210,000 ng/l in the Kaministikwia River downstream of a paper mill discharge (Flood et al., 1989), 243 ng/l in nearby Thunder Bay (Boyd, 1990), 842 ng/l at the mouth of the Don

River in Toronto (Boyd, 1988), and 710 ng/l in the Trent River, a major tributary of the Bay of Quinte (Poulton, 1990). Except for Thunder Bay, these values are above both the PWQO of 500 ng/l as well as GLWQA objective of 400 ng/l for the protection of aquatic life. During the period 1984-1988, levels of pentachlorophenol exceeded the PWQO in 4% of the samples and at six of the 25 river and stream monitoring sites; five of these were located downstream of pulp and paper mills or paper manufacturing industries (Whitehead, 1991).

Up to 0.0011 mg/kg (wet weight) of pentachlorophenol was associated with suspended sediment collected in the Rainy River downstream of a paper mill (Metcalfe and Hayton, 1989).

In a 1978 sediment core from the Bay of Quinte, pentachlorophenol concentrations reached their maximum of 0.061 mg/kg (dry weight) within the surficial (upper 3 cm) layers (Fox and Joshi, 1984). A maximum concentration of 0.550 mg/kg was recorded for the St. Lawrence River (Jaagumagi and Persaud, 1992).

Caged leeches exposed for three weeks in the Rainy River downstream of paper mill discharges, and in Thunder Bay Harbour near a wood preserving plant, accumulated up to 0.121 mg/kg and 5.300 mg/kg (wet weight) pentachlorophenol, respectively. Burrowing mayfly larvae, leeches and fathead minnows exposed to Thunder Bay Harbour sediments for ten days contained up to 0.068 mg/kg, 1.080 mg/kg and 0.061 mg/kg (wet weight), respectively (Metcalfe and Hayton, 1989). Oligochaetes from Canagagigue Creek (a tributary of the Grand River, which discharges to Lake Erie) contained up to 0.061 mg/kg (wet weight) (Jaagumagi et al., 1991a). Up to 0.172 mg/kg was accumulated by caged leeches exposed downstream of a phenolic resin plant on Frenchman's Creek, a Niagara River tributary (Anderson et al., 1991). Leeches exposed downstream of a wood-preserving plant in the Trent River (a major tributary of the Bay of Quinte) accumulated up to 19.0 mg/kg pentachlorophenol (Poulton, 1990).

Concentrations of up to 0.404 mg/kg (wet weight) by caged fathead minnows during a 96 hour exposure downstream of a paper mill discharge in Thunder Bay; concentrations in young-of-the-year walleye from the same study area were 0.113 mg/kg (Flood et al., 1989). Young-of-the-year yellow perch from downstream of a wood-preserving plant in the Trent River contained up to 1.963 mg/kg pentachlorophenol (Suns et al., 1991). This value is just below the New York State fish flesh criterion of 2 mg/kg (Newell et al., 1987) for the protection of fish-eating birds (Table 2.4).

Perylene

The environmental monitoring data base for this compound is relatively small compared to the other PAHs discussed here, since it is not always included in PAH analytical scans. Nevertheless, the data that are available indicate elevated concentrations in sediments and biota collected downstream of some Ontario sources. At some Great Lakes locations, sediment concentrations of perylene exceed the OMOE sediment quality guideline for 'total PAHs'. There are presently no criteria

for perylene in ambient water or aquatic biota. However, the GLWQA states that such contaminants should not be detectable in water or aquatic organisms (IJC, 1987).

Concentrations of perylene in surficial sediments ranged up to 11.0 mg/kg (dry weight) in the St. Marys River (Kauss and Hamdy, 1991). This value is above the OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs' and therefore there is concern over toxicity of this compound to the more sensitive species of sediment-dwelling organisms or possible biomagnification in the food chain (Persaud et al., 1991). Also, open water disposal of dredged sediment would be restricted.

Maximum concentrations of perylene in caged freshwater mussels were 0.021 mg/kg (wet weight) after a three week exposure in the St. Marys River (Kauss and Hamdy, 1991), and 0.028 mg/kg and 0.041 mg/kg, respectively, after 18 weeks in the St. Clair and Detroit Rivers (OMOE, unpublished 1984 data).

Phenanthrene

Monitoring data indicate elevated concentrations of phenanthrene in samples collected near or downstream of some Ontario point source discharges, and at some locations, sediment concentrations exceed the OMOE criterion for 'total PAHs'. There are presently no criteria for safe concentrations of phenanthrene in ambient water or aquatic biota. Nevertheless, the GLWQA states that such contaminants should not be detectable in water or aquatic organisms (IJC, 1987).

In the St. Marys River, whole water samples contained up to 587 ng/l (UGLCCS, 1988). Turkey Creek contained 170 to 180 ng/l and about 30 ng/l was found in Detroit River water downstream of this tributary (Cowell, 1990).

High concentrations of phenanthrene have been detected on fine particulate matter separated from water. For example, up to 8.379 mg/kg (dry weight) were associated with the suspended sediment phase in the St. Marys River (UGLCCS, 1988).

Concentrations of this PAH in surficial sediments ranged up to 1.12 mg/kg (dry weight) in Thunder Bay Harbour (EC, 1988), 22.40 mg/kg in the St. Marys River (Kauss, 1991), 8.51 mg/kg in the St. Clair River (OMOE, unpublished 1990 data), 5.58 mg/kg in the Grand River (Jaagumagi et al., 1991b), 189.0 mg/kg in Hamilton Harbour (Murphy et al., 1990), 20.00 mg/kg in Toronto's Ashbridges Bay (Jaagumagi et al., 1991d), 8.79 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992), 16.00 mg/kg in the Bay of Quinte (Poulton, 1990) and 12.99 mg/kg in the St. Lawrence River (Jaagumagi and Persaud, 1992). With the exception of Thunder Bay, these maxima exceed the OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs' and therefore, there is concern over the toxicity of phenanthrene to the more sensitive species of sediment-dwelling organisms, as well as its possible biomagnification in the food chain (Persaud et al., 1991). Also, open water disposal of contaminated sediment would be restricted.

Elevated levels of phenanthrene have been detected in freshwater mussels: maximum concentrations were 0.969 mg/kg (wet weight) in caged mussels exposed along the Ontario side of the St. Marys River (Kauss and Hamdy, 1991), 0.096 mg/kg in the St. Clair River and 0.025 mg/kg in the Detroit River (OMOE, unpublished 1984 data). In the Niagara River, mussels exposed in Chippawa Creek contained 0.071 mg/kg phenanthrene (Anderson et al., 1991).

Fathead minnows exposed to sediment from Muddy Creek, a tributary of Wheatly Harbour, accumulated 1.001 mg/kg (wet weight) (OMOE, EC, OMNR and OMAF, 1991). Burrowing mayfly larvae and fathead minnows exposed to contaminated Hamilton Harbour sediments accumulated up to 3.115 mg/kg and 1.412 mg/kg (wet weight), respectively (Krantzberg, 1991).

Phenanthrene has also been detected in young-of-the-year spottail shiners from a number of Great Lakes monitoring sites. These include 0.039 mg/kg (wet weight) at the Kaministikwia River and 0.048 mg/kg at Goulais Bay, both in Lake Superior, 0.034 mg/kg at Collingwood Harbour, 0.086 mg/kg at Mitchell Bay in Lake St. Clair, 0.086 mg/kg at Amherstburg in the Detroit River, and 0.039 mg/kg and 0.124 mg/kg at the mouths of the Humber River and Trent River, respectively, both in Lake Ontario (Suns et al., 1991).

Phenanthrene has been found in some dorsal fillet samples from adult sport fish caught in Ontario waters. For example, in the St. Marys River, the maximum concentrations in walleye, chinook salmon and pink salmon were 0.063 mg/kg, 0.084 mg/kg and 0.027 mg/kg, respectively. In the lower Niagara River, the highest concentrations found in walleye, rainbow trout, lake trout and American eel were 0.017 mg/kg, 0.045 mg/kg, 0.014 mg/kg and 0.037 mg/kg, respectively (OMOE, unpublished 1989 data).

Polychlorinated Biphenyls (PCBs)

PCBs were manufactured in the United States between 1929 and 1977 and used in North America as: cooling and insulating fluids in transformers and capacitors; hydraulic fluids; surface coatings for carbonless copy paper; plasticizer in sealants, caulkings, synthetic resins rubbers, paints, waxes and asphalts; as a flame retardant in lubricating oils; pesticide extenders; and in printing inks and adhesives. As of 1977 in Canada, PCBs are only allowed in existing close-system electrical and hydraulic systems and are to be replaced at the end of their service life (Cox and Ralston, 1990; deBarros, 1984).

PCBs have been detected in water, sediment and biota samples from most Great Lakes Areas of Concern. Their presence in the aquatic ecosystem at levels above criteria has resulted in beneficial use impairments throughout the Great Lakes for these media (Tables 2.4 and 2.5).

Lakewide mean water concentrations of total PCBs increase gradually as one progresses down through the Great Lakes: 0.325 ng/l in Lake Superior, 0.573 ng/l in Lake Huron, 0.676 ng/l in Georgian Bay, 1.159 ng/l in Lake Erie, and 1.201 ng/l in

Lake Ontario (IJC, 1989). At the outlet of Lake Ontario to the St. Lawrence River, mean concentrations during 1987 ranged from 1.32 ng/l to 1.34 ng/l (Tsanis et al., 1989). The above Lake Erie and Lake Ontario values, as well as the mean 'recombined whole water' concentrations at Fort Erie (3.90 ng/l) and at Niagara-on-the-Lake (1.66 ng/l) in the Niagara River (Niagara River Data Interpretation Group, 1988) and the average PCB concentrations in water at the head (1.4 ng/l) and mouth (3.3 ng/l) of the Detroit River (MDNR and OMOE, 1991) exceed the PWQO of 1 ng/l for the protection of aquatic life. Concentrations in some samples from Great Lakes nearshore areas have also exceeded the PWQO (Table 2.5). These locations, with their maximum levels, include 80 ng/l in Thunder Bay (Boyd, 1990), 1.14 ng/l in the Rainy River (Merriman, 1988), 950 ng/l in Nipigon Bay (OMOE, EC, OMNR and F&OC, 1991a), 30 ng/l in Hamilton Harbour (Poulton, 1986) and 230 ng/l in Toronto Harbour (Jaagumagi and Persaud, 1992)

PCBs tend to be associated with fine sediment particles in water. For example, concentrations detected in the suspended sediment phase were up to 0.060 mg/kg (dry weight) in Thunder Bay (Boyd, 1990), 0.240 mg/kg in the Rainy River (Merriman, 1988), 0.041 mg/kg in the St. Clair River and 0.032 mg/kg in the Detroit River (Johnson and Kauss, 1987), and 0.400 mg/kg in material collected from the Don River in Toronto (Boyd, 1988). A net increase in the daily loading between the head and mouth of the St. Clair River (0.3 kg/d) and a net decrease in the Detroit River (-2.1 kg/d) was calculated based on the above 1984 monitoring data. In the Niagara River, there was a significant increase of 0.411 kg/d in the suspended sediment-associated daily loading between Fort Erie and Niagara-on-the-Lake (Niagara River Data Interpretation Group, 1988).

Surficial sediments contain up to 0.185 mg/kg (wet weight) of total PCBs in Thunder Bay (Boyd, 1990), 0.495 mg/kg in Peninsula Harbour (Jardine and Simpson, 1990), 0.490 mg/kg in the St. Marys River (Jaagumagi et al., 1991c)), 0.120 mg/kg in Penetang Harbour (OMOE, EC, OMNR and OMAF, 1988), 0.355 mg/kg in Collingwood Harbour (Jaagumagi and Persaud, 1992), 2.580 mg/kg in the St. Clair River (OMOE and MDNR, 1991), 0.370 mg/kg in the Detroit River (Thornley and Hamdy, 1984), 0.630 mg/kg in Muddy Creek which discharges to Wheatly Harbour (OMOE, EC, OMNR and OMAF, 1991), 0.965 mg/kg in the Grand River (Jaagumagi et al., 1991b), 0.705 mg/kg in the Niagara River (Creese, 1987), 0.255 mg/kg in Port Weller Harbour (Jaagumagi and Persaud, 1992), 3.090 mg/kg in Hamilton Harbour (Jaagumagi and Persaud, 1992), 0.310 mg/kg, 1.590 mg/kg, 0.990 mg/kg, 0.465 mg/kg and 0.300 mg/kg in Toronto's Humber Bay, Inner Harbour, Ashbridges Bay, East Headland and Bluffer's Park, respectively (Jaagumagi and Persaud, 1992), 0.077 mg/kg in Port Hope Harbour (EC and OMOE, 1990), 6.140 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992), 0.880 mg/kg in the Trent River, a tributary of the Bay of Quinte (Poulton, 1990), 0.320 in the Bay of Quinte (Jaagumagi and Persaud, 1992) and 0.160 mg/kg and 1.010 mg/kg, respectively, near Maitland and Cornwall in the St. Lawrence River (Wilkins, 1988; OMOE and EC, 1990). These values exceed the 'lowest effect level' sediment quality guideline of 0.070 mg/kg. With respect to the latter guideline, these exceedances result in concerns over the toxicity of PCBs to the more sensitive species of sediment-dwelling organisms and possible biomagnification up through the food chain (Persaud et al., 1991). Also, open water disposal of dredged sediment would be restricted.

Phytoplankton collected near Sarnia organic chemical industry discharges to the St. Clair River contained up to 3000 mg/kg (dry weight) of PCBs (OMOE and MDNR, 1991). PCB concentrations in the filamentous alga Cladophora ranged up to 0.032 mg/kg (dry weight) along the Ontario shore of the Niagara River (Anderson et al., 1991) 1991). Midge larvae exposed to Midland Bay sediments accumulated 0.060 mg/kg (wet weight) of PCBs (OMOE, EC, OMNR and OMAF, 1988). Oligochaetes from sediments of Toronto's Humber Bay contained up to 0.60 mg/kg of PCBs (EC, OMOE, OMNR and MTRCA, 1989). Maximum concentrations accumulated by caged freshwater mussels exposed in Ontario waters were 0.148 mg/kg (wet weight) in the Rainy River (Hayton and Hollinger, 1989), 0.096 mg/kg along the Ontario shore of St. Clair River (OMOE and MDNR, 1991), 0.293 mg/kg in the Detroit River (MDNR and OMOE, 1991) and 0.039 mg/kg in Chippawa Creek, a tributary of the Niagara River (Anderson et al., 1991). Relative to the control, fathead minnows accumulated up to 0.63 mg/kg (wet weight) PCBs during exposure to Wheatly Harbour sediments (OMOE, EC, OMNR and OMAF, 1991).

PCB concentrations in recent (1986-1988) collections of young-of-the-year spottail shiners from the Great Lakes are significantly lower than in the 1970's. Nevertheless, concentrations in fish from 34 % of the 73 recent Great Lakes collection sites in Ontario waters exceeded the GLWQA specific objective of 0.1 mg/kg for the protection of birds and animals which consume fish (Suns et al., 1991), indicating a potential for reproductive toxicity in higher trophic levels. These locations included: Midland and Collingwood in Lake Huron; Lambton in the St. Clair River; Turkey Creek and Amherstburg in the Detroit River; Big Creek, Leamington and Port Dover in Lake Erie; the Welland River, Queenston and Niagara-on-the-Lake in the Niagara River; the Welland Canal, Twelve Mile Creek, Burlington Beach, Bronte Creek, Oakville Creek, Credit River, Mimico Creek, Humber River, Toronto Harbour, Leslie Spit and Napanee River in Lake Ontario; and Cornwall in the St. Lawrence River. In addition to increases in the number of collections which exceed the GLWQA specific objective, maximum levels of PCBs in these juvenile fish also increase somewhat as one progresses down through the Great Lakes. For example, the highest concentration in any of the recent Ontario collection sites was 0.067 mg/kg (wet weight) in Lake Superior, 'not detected' in the St. Marys River, 0.206 mg/kg in Lake Huron, 0.283 mg/kg in the St. Clair River, 0.040 mg/kg in Lake St. Clair, 0.214 mg/kg in the Detroit River, 0.385 mg/kg in Lake Erie, 0.256 mg/kg in the Niagara River, 0.321 mg/kg in Lake Ontario and 0.182 mg/kg in the St. Lawrence River (Suns et al., 1991). The maximum concentration of PCBs in adult sculpin from Collingwood Harbour was 0.11 mg/kg (OMOE and EC, 1989).

Although levels of PCBs in sport fish have also declined at some Ontario locations in recent years, restricted human consumption advisories for larger sizes of certain species are still widespread throughout the Great Lakes and some Ontario inland waters. These are related to concentrations above the Health and Welfare Canada guideline of 2.0 mg/kg. Such areas include Thunder Bay, Nipigon Bay, Jackfish Bay, Peninsula Harbour, Spanish River, Georgian Bay, Lake Huron, St. Clair River, Lake St. Clair, Detroit River, Lake Erie, Niagara River, Lake Ontario including Toronto and

the Bay of Quinte, and the St. Lawrence River at Cornwall (OMOE and OMNR, 1991).

PCBs are also present at elevated concentrations in the higher levels of the Great Lakes food chain, such as waterfowl, piscivorous birds and snapping turtles (Allan et al., 1991).

Polychlorinated Dibenzo-p-Dioxins and Furans

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are byproducts created during the manufacture of certain organochlorine pesticides (e.g., 2,4-D, 2,4,5-T, 2,4,5-trichlorophenol, pentachlorophenol, hexachlorophenol) or as a result of incomplete combustion (or reactions between) mixtures containing both chlorine and organic compounds (Cox and Ralston, 1990). One of the PCDDs, 2,3,7,8-TCDD, is an impurity in the herbicide 2,4,5-T (deBarros, 1984).

Elevated (above background or control) levels of these compounds have been found in water, sediment and biota samples from areas receiving industrial inputs, such as pulp and paper mills using chlorine bleaching. Their presence in the ecosystem at levels exceeding available criteria for fish has resulted in beneficial use impairments in certain locations in the Great Lakes Basin (Tables 2.4 and 2.5). At present, there are no sediment criteria for individual or total PCDDs and PCDFs.

PCDDs or PCDFs have been detected at low concentrations (below objective) in a few of the raw water samples collected at Ontario drinking water intakes in the St. Clair River (OMOE and MDNR, 1991) and the Detroit River (MDNR and OMOE, 1991).

Concentrations of up to 0.0115 µg/kg 2,3,7,8-TCDD (wet weight) and up to 0.149 µg/kg Octa-CDD were associated with the suspended sediment phase in the Rainy River downstream of discharges from pulp and paper mills (Merriman, 1988).

A survey of surficial sediments near Canadian pulp and paper mills using chlorine bleaching found that the presence of different PCDD and PCDF congeners and their abundance differed greatly in samples collected downstream of the discharges (Trudel, 1991). Due to the different toxicities of these compounds, this makes a comparison of the sites on the basis of toxicological significance difficult. Concentrations of the various congeners and isomers were therefore converted to toxic equivalent (TEQ) values using toxic equivalency factors in relation to 2,3,7,8-TCDD, the most toxic compound (NATO, 1988). For the ten locations in Ontario with such mills, the maximum 2,3,7,8-TCDD TEF concentrations in downstream sediments were: 0.017 µg/kg (dry weight) in the Rainy River, 0.208 µg/kg in Clay Lake, 0.019 µg/kg in the Kaministikwia River at Thunder Bay, 0.036 µg/kg in Nipigon Bay, 0.163 µg/kg in Jackfish Bay, 0.066 µg/kg at Peninsula Harbour, 0.019 µg/kg at Smooth Rock Falls, 0.023 µg/kg in the Spanish River, 0.046 µg/kg in the Old Welland Canal, and 0.108 µg/kg at Cornwall in the St. Lawrence River (Trudel, 1991). It should, however be noted that only at Clay

Lake, Nipigon Bay, Jackfish Bay, Peninsula Harbour, and Cornwall were these concentrations higher than at the upstream or control locations.

Sediment downstream of a phenolic resin plant in Frenchman's Creek, an Ontario tributary to the Niagara River, contained up to 0.210 µg/kg Hepta-CDD, 0.900 µg/kg Octa-CDD, 0.060 µg/kg Hexa-CDF, 0.440 µg/kg Hepta-CDF, and 0.440 µg/kg Octa-CDF (Anderson et al., 1991). Much higher concentrations of PCDDs and PCDFs were found in Thunder Bay Harbour sediments adjacent to a wood preserving plant; i.e, up to 0.32 µg/kg Tetra-CDD, 1.90 µg/kg Penta-CDD, 7.30 µg/kg Hexa-CDD, 480 µg/kg Hepta-CDD, 1700 µg/kg Octa-CDD, 0.070 µg/kg Tetra-CDF, 0.320 µg/kg Penta-CDF, 7.700 µg/kg Hepta-CDF, 51 µg/kg Hepta-CDf and 99 µg/kg Octa-CDF (EC, 1988). For comparison, levels in sediments of the Pettit Flume on the U.S. side of the Niagara River were 9 µg/kg 2,3,7,8-TCDD, 620 µg/kg Tetra-CDD, 560 µg/kg Penta-CDD, 980 µg/kg Hexa-CDD, ~360 µg/kg Hepta-CDD, ~400 µg/kg Octa-CDD, 1700 µg/kg Tetra-CDF, 2700 µg/kg Penta-CDF, 7400 µg/kg Hexa-CDF, ~3900 µg/kg Hepta-CDF and ~13000 µg/kg Octa-CDF (Anderson et al., 1991)

Shrimp (Mysis relicta) from Jackfish Bay contained 9 ng/kg (wet weight) of 2,3,7,8-TCDD, 48 ng/kg Tetra-CDF, 16 ng/kg penta-CDF and trace levels of Penta-CDD, Hexa-CDD, Hexa-CDF and Hepta-CDF. After three weeks of exposure in Jackfish Bay, caged mussels accumulated 34 ng/kg Tetra-CDF and trace levels of Tetra-CDD (Sherman et al., 1990). The maximum concentration of 2,3,7,8-TCDD accumulated over three weeks by caged freshwater mussels exposed in Ontario waters of the Rainy River was 5.4 ng/kg (wet weight). These mussels also contained up to 20 ng/kg Hepta-CDD and 8.2 ng/kg Octa-CDD (Hayton and Hollinger, 1989). In the Niagara River, caged mussels from Ontario sites contained up to 5 ng/kg Hepta-CDD, 7 ng/kg Octa-CDD and 63 ng/kg Tetra-CDF after three weeks. In contrast, mussels exposed along the U.S. shore of the upper river at the Pettit Flume accumulated 200 ng/kg 2,3,7,8-TCDD, 3400 ng/kg Tetra-CDD, 3300 ng/kg Penta-CDD, 200 ng/kg Hexa-CDD, 70 ng/kg Octa-CDD, 20000 ng/kg Tetra-CDF, 55000 ng/kg Penta-CDF, 10000 ng/kg Hexa-CDF, 3800 ng/kg Hepta-CDF and 3300 ng/kg Octa-CDF (Anderson et al., 1991). In the St. Lawrence River at Cornwall, caged mussels accumulated up to 5 ng/kg Tetra-CDF and 3 ng/kg Penta-CDF (OMOE and EC, 1990).

Young-of-the-year spottail shiners collected from the Ontario nearshore of the St. Clair River in 1985 contained 274 ng/kg (wet weight) Penta-CDF (OMOE and MDNR, 1991). In 1981, the average concentration of 2,3,7,8-TCDD in spottail shiners from Niagara-on-the-Lake in the lower Niagara River (14 ng/kg, wet weight) exceeded the New York State fish flesh criterion of 3 ng/kg for 'total TCDDs' established by Newell et al. (1987) to protect fish-eating birds and mammals. Concentrations at this location decreased to 'not detected' in 1982 and 1983 collections (Suns et al., 1983).

There are presently restrictions on the consumption of some sport fish species from Lake Superior, the Niagara River, and Lake Ontario due to concentrations above the Health and Welfare Canada guideline for human consumption of 0.00002 mg/kg (= 20 ng/kg) 2,3,7,8-TCDD (OMOE and OMNR, 1991; Allan et al., 1991). Elevated levels

of PCDDs and PCDFs have also been detected in the eggs of herring gulls and snapping turtles from areas receiving industrial inputs (Allan et al., 1991).

## Toxaphene

Toxaphene is a complex mixture of at least 117 chlorinated camphenes (deBarros, 1984). At present, there are no documented use impairments by this organochlorine pesticide in Ontario. However, there is presently no criterion for safe concentrations of this compound in sediments (Table 2.4).

Mean concentrations of toxaphene reported for Great Lakes whole water samples are 0.5 ng/l in Lake Superior, 1.6 ng/l in Lake Huron, 0.7 ng/l in Lake Erie and 0.6 ng/l in Lake Ontario (Strachan and Eisenreich, 1988). Monitoring data for selected Ontario tributaries indicate that toxaphene is not present in water samples at the routine analytical method reporting limit of 500 ng/l (OMOE, unpublished data). However, this is above the GLWQA specific objective and the PWQO guideline of 8 ng/l for the protection of aquatic life. Toxaphene has not been detected (at a method reporting limit of 0.200 mg/kg dry weight) in sediment samples from Toronto (Jaagumagi et al., 1991d).

Toxaphene has not been detected (at a method reporting limit of 0.01 mg/kg wet weight) in samples of benthic macroinvertebrates or of sediment bioassay organisms (mayfly larvae and fathead minnows) from such Ontario study areas as the St. Marys River (Jaagumagi et al., 1991c), Canagagigue Creek (Jaagumagi et al., 1991a), the Grand River (Jaagumagi et al., 1991b) and Toronto (Jaagumagi et al., 1991d). Toxaphene was not detected (at a method reporting limit of 0.200 mg/kg wet weight) in caged mussels exposed for three weeks in the Niagara River and in the Welland River (Anderson et al., 1991).

This pesticide has also not been detected in samples of minnows or of resident bottom-dwelling sculpins from the above areas studied by Jaagumagi et al.

There is presently no official Health and Welfare Canada guideline for the protection of human consumers of fish. However, concentrations of toxaphene in sport fish from a number of Ontario locations, when detected, have not exceeded the provisional guideline of 3.0 mg/kg used by the province (Cox and Ralston, 1990).

## Tributyltin

Of the organotin compounds used in Canada, diorganotins are mainly used as plastic stabilizers or feed additives, triorganotins as biocides, and tetraorganotins as industrial catalysts (Wong and Chau, 1990). The most significant environmental usage of tributyltin is as the active ingredient in antifoulant paints (either as the fluoride or oxide) that are applied to boat hulls to prevent growth of attached algae and bacteria (Jones and Millson, 1982; Wong and Chau, 1990). Tributyltin oxide is also used as a slimicide in cooling water towers and as a wood preservative (Jones and Millson, 1982).

There are presently no criteria for safe concentrations of tributyltin (TBT) in receiving waters, sediment or aquatic biota. More importantly, the present lack of routine OMOE analytical methods for these matrices or for effluents precludes the ability to determine loadings to the environment. Environment Canada has however, been testing for organotins in the Great Lakes in recent years.

Although not detected in subsurface water samples from the St. Clair River, TBT was found in surface microlayer samples from two of the stations sampled, with a maximum concentration of 33 ng/L (as tin) (Maguire et al., 1985). In the Detroit River, TBT was found in subsurface water samples from eight of 23 stations sampled, with a maximum concentration of 38 ng/L in Ontario waters and 70 ng/L in Michigan waters.

Sewage treatment plant effluent and sludge samples were collected from three cities (Sarnia, Toronto, and Hamilton) and analyzed for butyltin compounds (Chau et al., 1992). Monobutyltin was found in all effluent samples. Monobutyl-, dibutyl-, and tributyltin were found in sludge samples collected from Toronto and Sarnia.

The maximum concentration of TBT found in the St. Clair River sediments was 0.007 mg/kg, whereas in the Detroit River it ranged as high as 0.008 mg/kg in Ontario and 0.072 mg/kg in Michigan (Maguire et al., 1985). TBT concentrations of up to 0.045 mg/kg and 0.055 mg/kg were found in Oshawa and Whitby Harbours, respectively (Chau et al., 1989).

In a survey of Severn Sound, an Area of Concern with numerous marinas, tributyltin was found in sediments from as many as 14 of the 18 stations sampled. Concentrations varied seasonally, with maxima of 0.444 mg/kg (dry weight) being detected in the spring, 0.392 mg/kg in the summer, and 0.163 mg/kg in the fall (Wong and Chau, 1990). Dibutyltin and monobutyltin, degradation products of tributyl tin, were also detected in some sediment samples, but not in biota.

In the same study, five of 11 caged mussels from different stations contained tributyltin concentrations of 0.059 mg/kg to 0.066 mg/kg (wet weight). Young-of-the-year fish from two areas in Severn Sound contained from 0.009 mg/kg to 0.040 mg/kg. Northern pike contained up 0.240 mg/kg in the spring but no tributyltin in the fall. This seasonal variation was thought to be related to the release of tributyltin from the sediments (see above) and the leaching of this compound from freshly-painted boats placed in the water (Wong and Chau, 1990).

Chau et al. (1989) reported accumulations of up to 0.091 mg/kg and 0.682 mg/kg in caged mussels exposed in Oshawa and Whitby Harbours, respectively.

## Trifluralin

Trifluralin is a nitrogen-containing herbicide that can be both persistent and bioaccumulative (Verschueren, 1983). However, with the exception of surface and drinking water, there are presently no criteria for safe concentrations of this compound in sediments or in aquatic biota. Agricultural uses in Ontario are

associated with the growth of certain field crops, fruits and vegetables (Moxley, 1989).

No Ministry data is available on trifluralin concentrations in water and there is currently no analytical capability for the determination of this compound in sediments or aquatic biota.

## Appendix 'C'

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